2015 CLIMATE CHANGE AND HEALTH RESILIENCY REPORT

RHODE ISLAND DEPARTMENT OF HEALTH CLIMATE CHANGE PROGRAM

CDC Climate-Ready Cities and States Initiative
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Award # 5UE1EH001040-03
Building Resilience Against Climate Effects in State, Territorial and Tribal Health Departments

Climate Change Program
The Rhode Island Department of Health
Division of Community, Family, Health, and Equity
Healthy Homes and Environment

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Thank you to our contributing authors and researchers for their hard work and support for this project. From the Brown University School of Public Health, Professor Greg Wellenius, Melissa Eliot, and Samantha Kingsley have helped immensely with epidemiological support, our interns Alex Durand and Amy Sung, both students at Brown University, contributed to various sections in the report. Amie Parris and Sean McCormick, colleagues at HEALTH, contributed to the sections on Water Quality and Vibrio.

The issue of climate change is one that requires maximum collaboration and our work would not be possible without the help of our numerous partners throughout Rhode Island and within the CDC's BRACE community. The full list of our partners in included at the end of the report.

Dear Colleagues,

The destabilizing effects of climate change on our environment are among the most significant potential health threats faced by individuals and Rhode Island communities today. Our mental health, physical health, the infrastructure of our cities and towns, and the safety of our food and water will all be impacted by more frequent heat waves, storms, droughts, floods, and sea level rise. In Rhode Island, where our economy, culture, and identity are all so closely tied to the ocean and to Narragansett Bay, the effects of climate change will be particularly acute.

Although the scale and intensity of future climate change impacts are uncertain, we can certainly prepare for these changes and adapt to make Rhode Island as safe, healthy, and resilient as possible. The Rhode Island Department of Health (HEALTH) is partnering with leaders throughout the state on this important work. For example, HEALTH and Brown University are studying the effects of temperature on morbidity and mortality and HEALTH and the Rhode Island Division of Elderly Affairs are examining ways to make elderly housing in our state more resilient. In the months and years to come, holistic collaboration will be essential across healthcare, education, transportation, and environmental management, among other fields.

This Climate and Health Resiliency Report builds on existing research and lays out the effects of climate change in Rhode Island with great clarity and detail. It includes valuable tools and diagrams, such a social vulnerability index by census tract and various data projections, such as increases in heat-related emergency department visits over the next 70 years. This report can be used by organizations throughout our state to set priorities and goals together and to outline a path forward toward a safer, healthier Rhode Island.

If you are interested in learning more about climate change and climate change programs in Rhode Island, don't hesitate to contact HEALTH. Because good public health policy is a result of spirited collaboration, we welcome insight and thoughts from throughout the state.

Thank you for all the work that you do to protect and promote the health and safety of Rhode Islanders.

Sincerely,

Michael Fine, M.D.
Director of Health

Aerial Photo of Port of Providence

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"In the face of challenge, we need champions throughout the world who will work to put protecting human health at the center of the climate change agenda."[i]

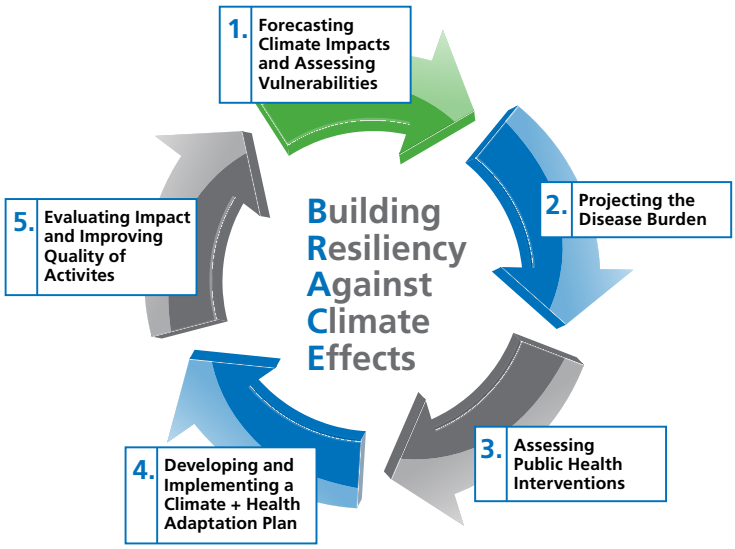
Dr. Margaret Chan
World Health Organization Director-General[1]

INTRODUCTION

The Rhode Island Department of Health, Climate Change Program

Funded by The Centers for Disease Control and Prevention (CDC), the Rhode Island Department of Health (HEALTH) Climate Change Program is part of a national effort to anticipate and prepare for human health effects related to global and local climate change. CDC's Building Resilience Against Climate Effects (BRACE) framework is focused on integrating epidemiological data and climate change models to develop projections, identify vulnerabilities, and inform public health planning. The national effort includes the participation and collaboration of sixteen states and two cities. Five New England states, plus New York and New York City participate in a regional collaborative of BRACE programs.

FIGURE 1. THE BRACE FRAMEWORK

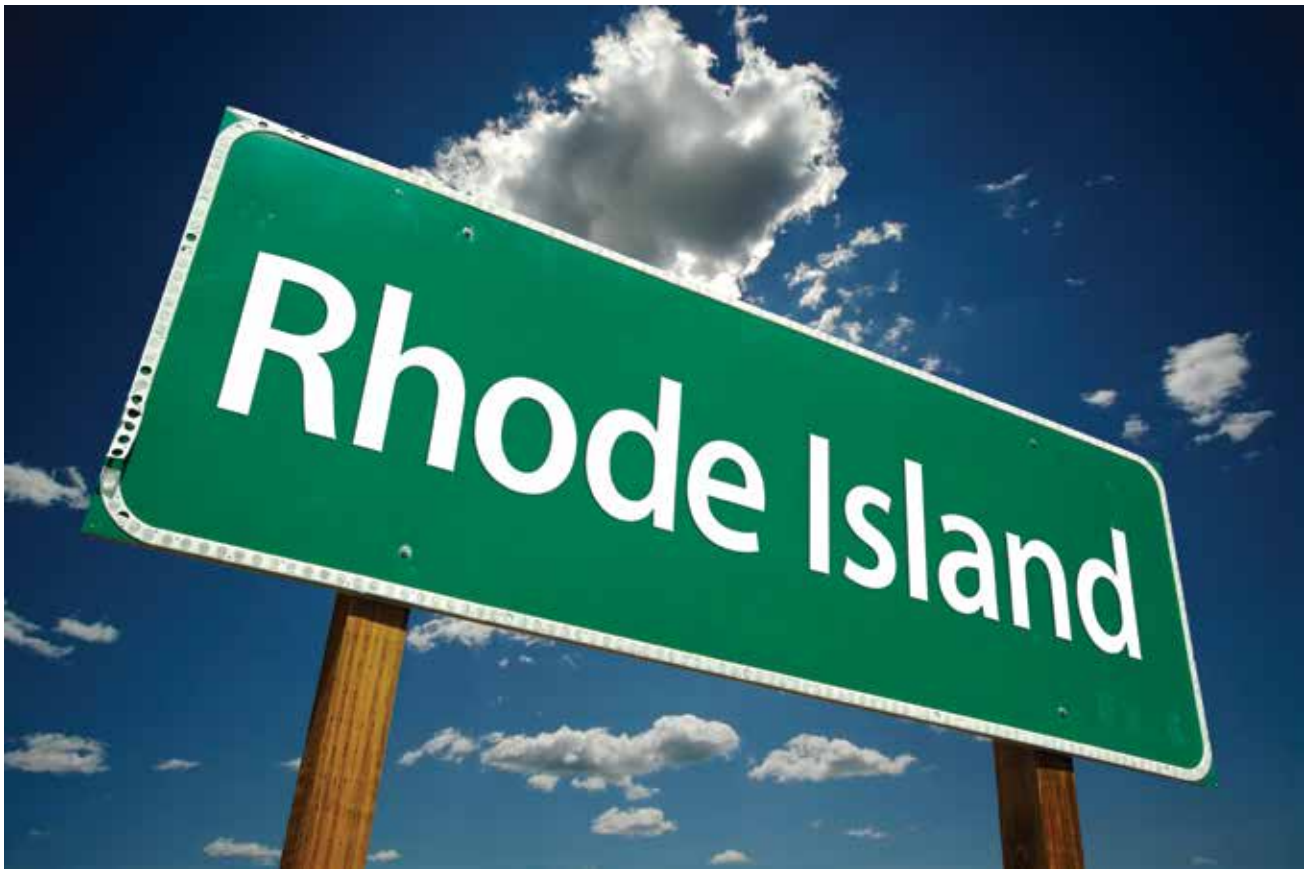


The Rhode Island Department of Health's Climate Change and Health Resiliency Report synthesizes research on climate change impacts on human health, identifies the threats climate change poses to the well-being of Rhode Islanders, and describes best practices that can strengthen the capacity and effectiveness of public health interventions addressing climate impacts in the state. The report fulfills the requirement in legislation that was enacted in July 2014 in Rhode Island to "[d]evelop a climate and health profile report that documents the range of health impacts associated with climate change and identifies the most vulnerable populations." R.I.G.L 42-6.2-3(10).* It also completes action item 6.3.1 in the June 2014 report *A Resilient Rhode Island, Being Practical about Climate Change*, submitted by the Rhode Island Executive Climate Change Council. With this report, HEALTH hopes to contribute to efforts to enhance resilience to the threat of climate change and support the inclusion of public health within the many discourses and efforts addressing the issue at local, state, regional and national levels.

The Rhode Island Department of Health Climate and Resiliency Report is the first step to the development of a climate and health adaptation plan for the Department. The report describes the threats that climate change poses to the State and its particularly vulnerable populations and offers best practices to counter these threats and protect vulnerable groups. The report highlights the Climate Change Program's current activities and pilot projects. In addition, personal stories from Rhode Islanders are included as part of our *Faces of Climate Change* interviews.

The report contains separate sections for seven climate and health impacts faced in Rhode Island: heat, air quality, extreme weather, water quality, vibrio, vector-borne disease and mental health. Each section covers the primary health impacts, climate projections, vulnerable populations, best practices, current projects, and next steps.

***Commonly referred to as the Resilient Rhode Island Act,** the law codifies an earlier executive order, establishing the Executive Climate Change Coordinating Council, which is tasked with coordinating work by state agencies to mitigate the effects of climate change to the extent possible (the law sets specific greenhouse gas emission reduction targets), as well as develop effective adaptation strategies; coordinating with local and federal governments as well as the private sector, including educational institutions; and improving public understanding of, and engagement in, matters of climate change. The Act emphasizes resilience as a positive and practical rallying theme for collaboration across sectors and disciplines. It directs all state agencies to incorporate climate resilience into their planning, decision-making and operations. A public Advisory Board representing multiple sectors as well as a Science and Technical Advisory Board are established to assist the Council. More information on the legislation and the work of the Council, including its report, can be found at www.planning.ri.gov/statewideplanning/climate.



Our Changing Climate

The Climate and Health Resiliency Report uses data and projections provided by TetraTech, a global engineering and consulting service, as well as data provided by the National Oceanic and Atmospheric Administration (NOAA), the National Climate Assessment, and other resources to describe the changes in Rhode Island's climate that have already occurred and to predict how climate will change in the future.

Average global temperatures have risen significantly since pre-industrial times. Eleven of the past twelve years are among the twelve warmest years on instrumental record (since 1850), and the global average surface temperature has risen roughly 1.5 degrees Fahrenheit in this time period.[2] These temperature increases are associated with increases in atmospheric levels of fossil fuel combustion products as well as impacts from changing land-use patterns. Research sponsored, synthesized and analyzed by the Intergovernmental Panel on Climate Change estimates that global temperatures will rise as much as 8°F by the end of the century.[3] Sophisticated predictive modeling gives us an idea of how these increased temperatures promote large scale changes in ocean acidification, sea-level rise, and increased frequency and intensity of extreme weather events.

Climate change poses new and unfamiliar threats to human health around the world. Climate change compromises the stability of ecological and evolutionary relationships that sustain life on earth, impacting human health in ways that are many and varied. In addition to the seven impacts described in separate sections of this report, climate change affects morbidity and mortality from natural disasters, global food security, access to safe water, and more.

Future climate

Climate change will result in both general shifts in the baseline environment and greater frequency and intensity of extreme weather events. The magnitude of climate change depends primarily on the amount of warming caused by greenhouse gas emissions, land-use changes, and the climate's sensitivity to emissions. The workings of climate and Earth systems are extremely complex, and climate models sometimes disagree about the exact nature of future changes. Nevertheless, confidence in climate change projections has increased.

By 2100

- Average global temperature may rise as much as 8°F
- Sea level may rise as much as 3-5 feet
- Summer heat advisories and air quality alerts will become more frequent
- Winters will become increasingly shorter, warmer, and wetter
- Flood events will become more frequent
- Hurricanes and storms will become more intense

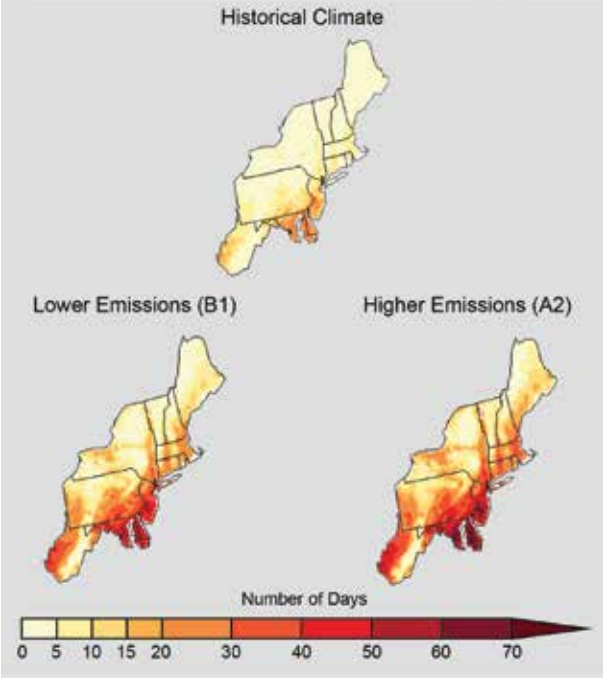
Climate Change in Rhode Island

Climate change impacts seen in Rhode Island include more frequent heat waves, heavy downpours, drought, storms, and flooding.

Mean annual temperatures are rising significantly. Since 1895, average temperatures in the Northeast have increased by 2°F.[4] Rhode Island climate change models predict that this average will continue to rise at an accelerating rate, potentially climbing another 1.6°F by 2022 and as much as 5.7°F by 2084.[5] Although they may seem minor, these small changes in average temperature are driving a significant transformation in the region's weather patterns. For example, some parts of the Northeast are projected to experience an average of 60 additional 90°+ days per year between 2041 and 2070.[6] By 2085, the total number of heat advisories (a measure of the combined effects of heat and humidity) is projected to increase from 51 per summer to 70, and the

number of more serious "Danger" heat advisories increasing from 1 to 4.[7] Because warmer air has a greater capacity to carry moisture, this warmer air will also be much more humid. The combination of heat and humidity will exacerbate the health impacts of rising temperatures and make the perceived temperature feel even hotter.

FIGURE 2. PROJECTED INCREASES IN THE NUMBER OF DAYS OVER 90˚F



Projected increase in the number of days per year with a maximum temperature greater than 90°F averaged between 2041 and 2070, compared to 1971-2000, assuming continued increases in global emissions (A2) and substantial reductions in future emissions (B1). (Figure source: NOAA NCDC / CICS-NC).

The intensity of Atlantic hurricanes is likely to increase. Since the 1980s, Atlantic hurricane activity has increased substantially.[8] Predicting future hurricane activity is extremely complex; predictive models do not always agree. The most recent National Climate Assessment synthesizes the results of many models of Atlantic storm activity. The models project a slight decrease in total yearly number of hurricanes, but predict an increase in the number of Category 4 and 5 hurricanes.[9] The models tend to agree that rainfall rates in hurricanes will increase in a warmer climate. Increased hurricane precipitation combined with Rhode Island's sea level rise indicates that the effects of storm surge will increase markedly during hurricanes. With a 3 foot rise in sea level, even a Nor'easter (extra-tropical storm) could submerge coastal areas of the state, cutting off the southwestern peninsula of Newport from the mainland.[10] The experience of Hurricane Sandy also suggests the potential for hurricanes to become significantly larger in diameter, affecting a broader geographic area and further straining response and recovery resources.[11]

Rhode Island's sea level is rising faster than the global average. Sea levels have been rising for more than a century following a millennium of little change. Global measurements from tide gages and satellite altimetry show that the rate of sea level rise has accelerated in recent years, nearly doubling since 1993.[12,13] In Rhode Island sea level is rising faster than the global average, due in part to land subsidence and in part to changes in ocean circulation patterns as a result of climate change.[14] Various studies predict that sea level may be several feet higher than today's levels by the turn of the century. (See references below). This trend will continue well into the future beyond the end of this century due to the melting of the Greenland and West Antarctic ice sheets that add water to the ocean basins.[15] A study by TetraTech for the RIDOH modeled anticipated sea level rise of 0.26 to 0.65 feet by 2022, 0.76 to 1.54 feet by 2052, and 1.43 to 2.92 feet by 2084. The RI Coastal Resources Management Council sea level rise policy expects a 3 to 5 foot sea level rise by 2100 for coastal management and adaptation planning. Both the TetraTech study and CRMC policy should be considered as a minimum for planning efforts, particularly for the siting and construction of critical public infrastructure.[16,17]

Various studies predict that sea level may be several feet higher than today's levels by the turn of the century (References)

1. Grinstead et al 2010 – Reconstructing sea level from paleo and projected temperatures 200 to 2100AD.
2. Vermeer & Rahmstorf 2009 – Global sea level linked to global temperature
3. Pfeffer et al. 2008 –Kinematic constraints on glacier contributions to 21st century sea-level-rise.
4. Rahmstorf 2007 – A semi-empirical approach to projecting future sea level rise.
5. Jevrejeva et al 2011 – Sea level projections to AD2500 with new generation of climate change scenarios.

Increases in sea level elevations will impact Rhode Island's low-lying coastal communities. Some areas will be flooded at high tides and eventually be permanently inundated. Storm surges will be higher and penetrate farther inland than at present. Moreover, storm surges that were experienced only during rare events will become more frequent occurrences as sea level continues to rise. Damages will increase to homes and infrastructure in coastal areas, including health care facilities, water and sewer systems, transportation networks and the energy grid. Sea level rise will result in groundwater intrusion into coastal aquifers and affect drinking water supplies. Additionally, it may result in the displacement of coastal populations.

Extreme precipitation and flood events are becoming more frequent and extreme. Flooding is already one of the major natural hazards affecting Rhode Island. Climate models indicate that heavy rain events in Rhode Island will become less regular but more intense, which may result in more frequent and extreme flooding along the State's river systems, coastline, and any areas that do not have adequate infiltration or stormwater controls.[18] In 2010 alone, the State experienced two "100-year" (or 1% annual chance) floods and increased precipitation intensity will significantly worsen the impact of such incidents. Since 1991, the Northeast has already seen an 8% increase in overall precipitation and, since 1958, a 71% rise in heavy rain events.[19] Flood modeling indicates that, with a 3-foot rise in sea-level, a 1% annual chance flood event for Providence would inundate all coastal regions near Providence Harbor, most of Downtown, South

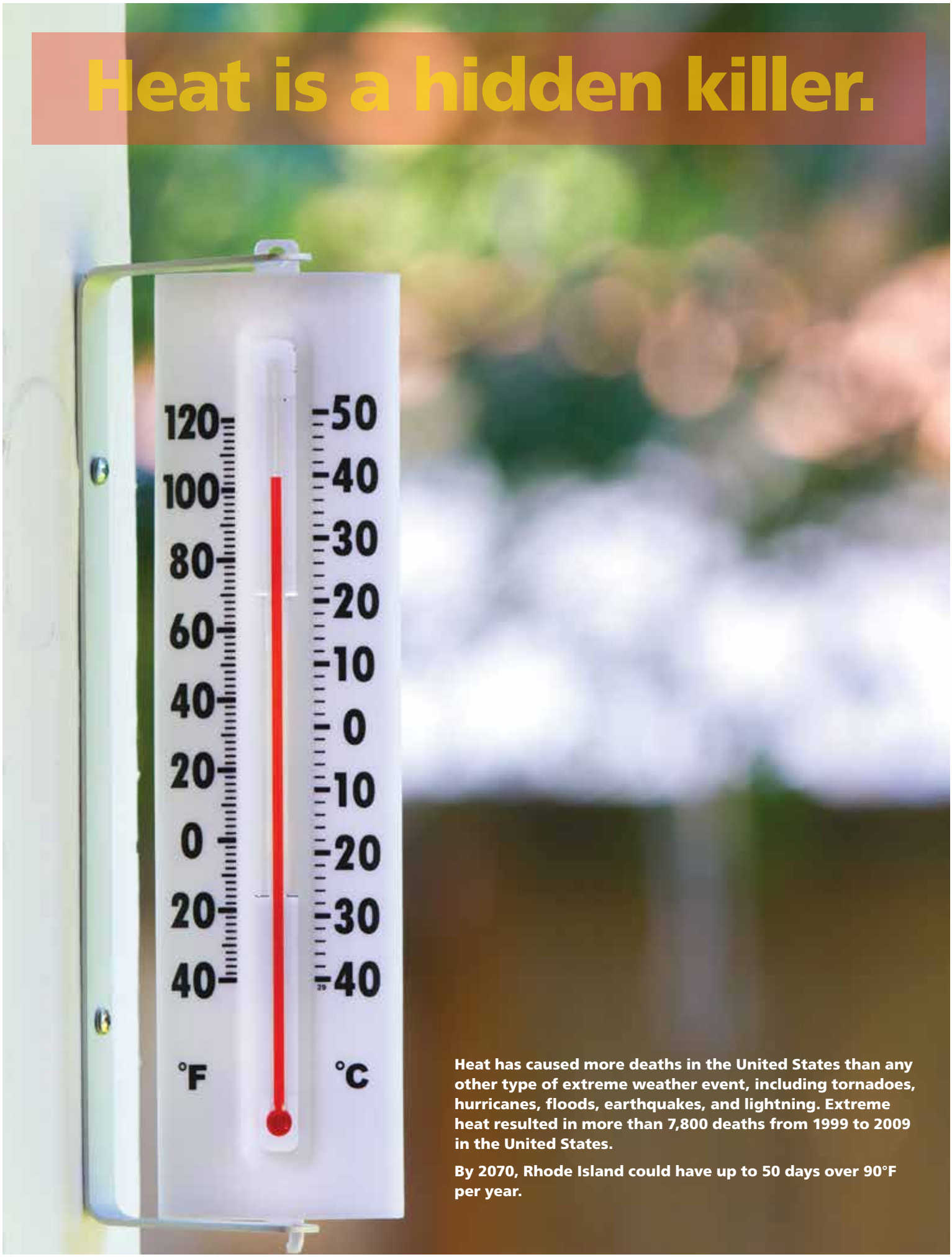
Flooding at Rhodes on the Pawtuxet, Cranston

Elmwood, and Washington Park neighborhoods.[20] The impact of a similar event in Newport would be even more devastating, submerging large portions of southern and western Newport.[21] Flood events are likely to result in proliferation of waterborne diseases, contamination of local waterways, damage to homes and businesses, infrastructure loss, widespread psychological trauma, and long-term effects on local economies.[22]

Winters are becoming shorter and wetter. Although New England winters are expected to become shorter and warmer over the coming decades, climate models suggest that precipitation in the Northeast will increase during the winter months.[23] The number of freezing (below 32°F) days is expected to decrease significantly in the Northeast, by approximately 20 to 23 days.[24] This warming increases the possibility of a greater number of freeze/thaw cycles, with more sleet or freezing rain events and less snow overall. Meanwhile, the same forces that increase the strength and precipitation of hurricanes may generate stronger and more frequent winter storms in the region.

Droughts are likely to occur as often as once per summer. Rhode Island's Hazard Mitigation Plan indicates that the State currently has a 5% chance of experiencing a drought in any given year.[25] However, as rising temperatures lead to greater rainfall variability, it is increasingly likely that Rhode Island will begin to experience more frequent seasonal droughts in the summer and fall.[26] Even such short-duration events are likely to result in water shortages, crop damages, stream-flow reduction, and depletion of ground water and soil moisture. Droughts are also associated with impacts to drinking water quality as low flow rates concentrate chemicals, nutrients, and soil particulates while lowering concentrated oxygen.[27]

Heat is a hidden killer.



Heat has caused more deaths in the United States than any other type of extreme weather event, including tornadoes, hurricanes, floods, earthquakes, and lightning. Extreme heat resulted in more than 7,800 deaths from 1999 to 2009 in the United States.

By 2070, Rhode Island could have up to 50 days over 90°F per year.

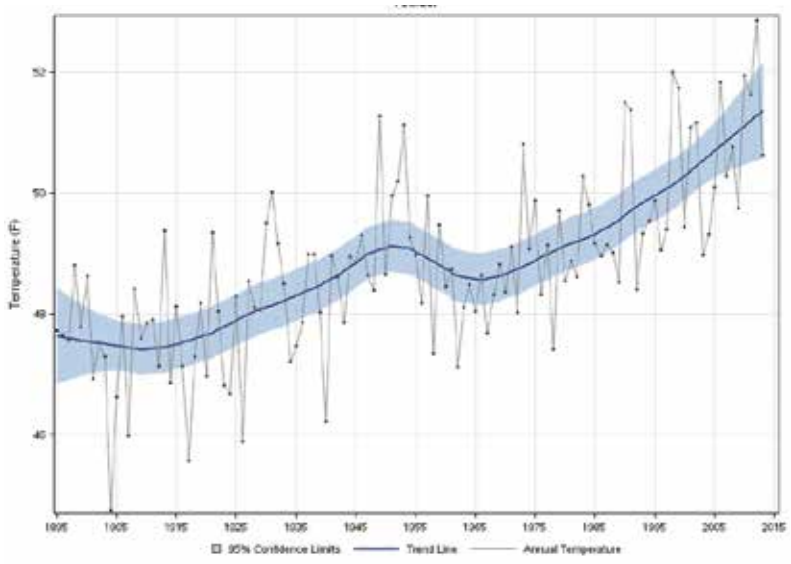
EXTREME HEAT AND RISING TEMPERATURES

Health Effects

Heat is a hidden killer, as it has caused more deaths in the United States than any other type of extreme weather event, including tornadoes, hurricanes, floods, earthquakes, and lightning.[28] With climate change, extreme heat and hot weather have already increased in frequency and magnitude. In 1970, Providence had 4 days with a maximum temperature over 90°F and in 2013 this number had risen to 22 days.[29] Figure 3 also shows the upward trend of our annual average temperatures from 1895 until today. Potential health effects of rising temperatures and extreme heat include heat cramps, heat exhaustion, dehydration, increased hospitalizations, and even death. In fact, extreme heat resulted in more than 7,800 deaths from 1999 to 2009 in the United States.[1] Most of these deaths occurred due to heat waves, or prolonged periods of unusual and extreme heat.[30] Since 1999, heat was the attributable cause of 18 Rhode Island deaths.[31] While this is not a large number, deaths from heat are preventable. Heat waves are predicted to increase in both frequency and scale due to climate change, potentially inducing more heat-related illness and death. In addition to extreme heat events, rising maximum daily temperature, or the highest temperature on a certain day, also impacts health. Thus, the potential public health consequences of climate change become more significant as the effects of increasing temperatures become more pronounced.

Heat is a hidden killer, as extreme heat has caused more deaths in the United States than any other type of weather event, including tornadoes, hurricanes, floods, earthquakes, and lightning.

FIGURE 3. RHODE ISLAND MEAN TEMPERATURE - ANNUAL



Historical annual average temperature from 1895-2013 in Rhode Island. (NOAA National Climatic Data Center)

Vulnerable Populations

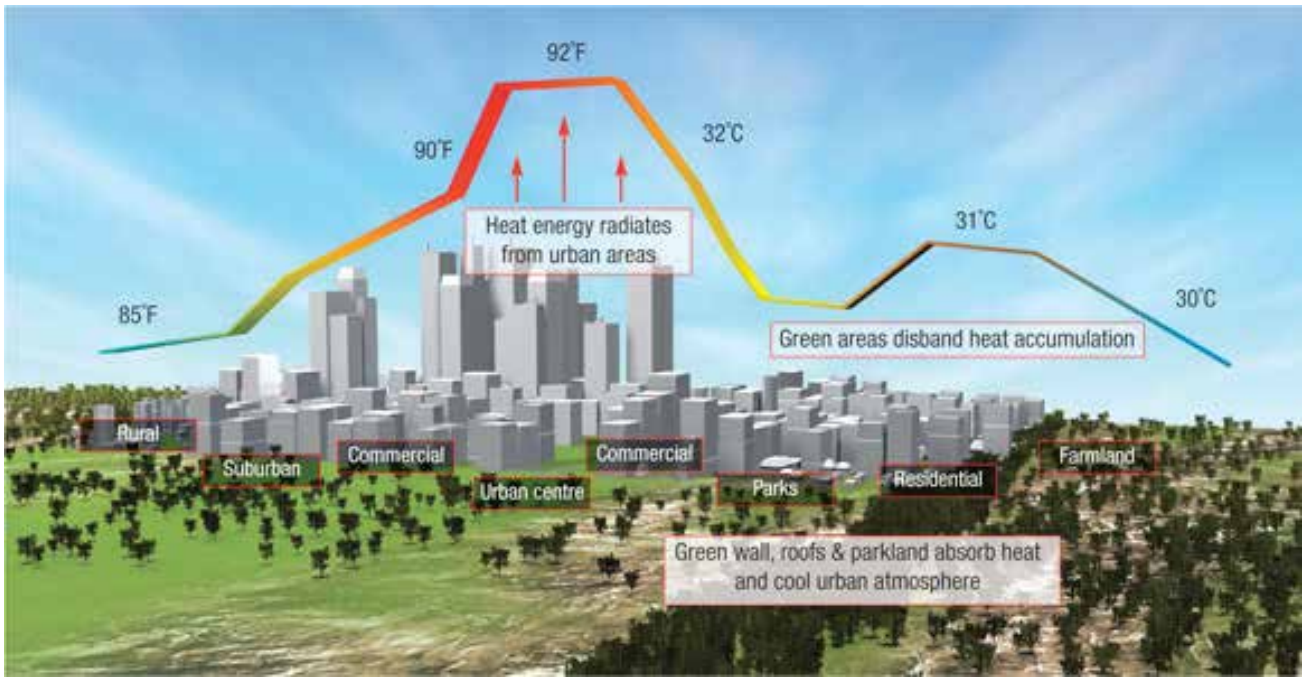
During heat events, people adapt by changing their behavior, for example, by seeking shade, and through their body's natural responses, e.g., increased blood flow to the skin. Vulnerability to heat increases when either physical or behavioral responses are compromised. Physical responses are impacted by age (young children and those over 65 are most vulnerable), by some pre-existing health conditions, by some types of medication, and one's level of acclimatization to the temperature. Behavioral adaptive responses can be disrupted by a variety of factors, including limited access to social or financial resources, social isolation, mental illness, or geographic location of residence or workplace.

Vulnerable Groups:

- Children
- Older Adults
- Individuals with pre-existing medical conditions
- People with limited social or financial resources
- Urban Residents
- Outdoor workers
- Un-acclimatized

Rhode Island's Heat Islands: Temperatures are not uniform across Rhode Island. According to the 2010 US Census, over 90% of Rhode Island residents live in areas defined as urban.[32] Many of these urban areas can be defined as heat islands. The urban heat island effect is the phenomenon by which cities tend to have higher average temperatures compared to their surroundings, resulting from the prevalence of man-made materials that absorb sunlight and reduced green space.[33,34](See Figure 4.) Rhode Island's urban heat islands coincide with low income communities where housing most frequently lacks insulation, good ventilation and access to air conditioning that provide protection from heat. When populations that are vulnerable to heat because of age, health, or social status live in areas that are more likely to experience extreme heat, the risk of heat-related illness increases. As the rate of urbanization continues to rise, the urban heat island effect will play a larger role for heat-related illness and the number of hospitalizations as a result.

FIGURE 4. HEAT ISLAND EFFECT



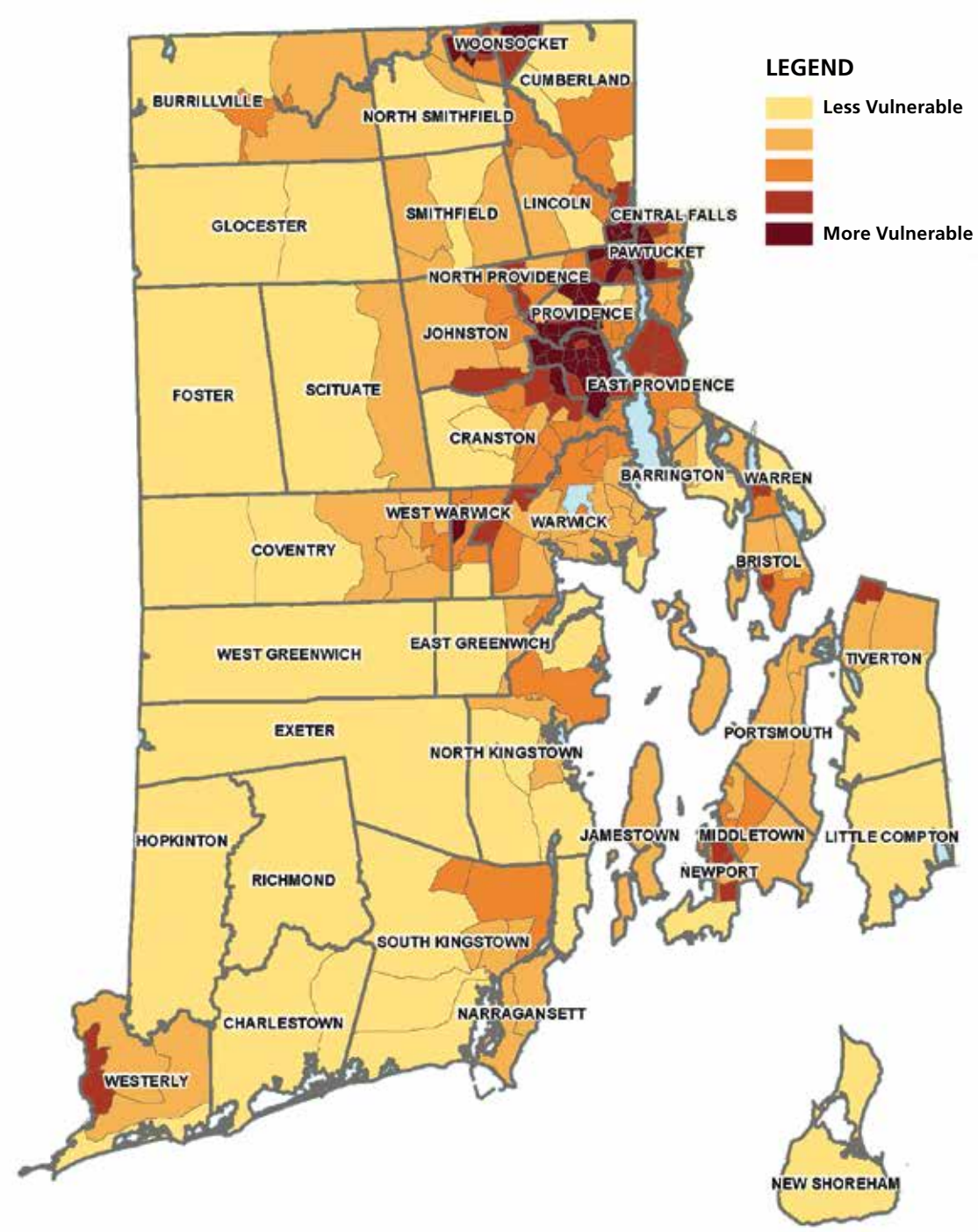
According to the CDC, "social vulnerability refers to the resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss."[35]

In partnership with the ProvPlan, HEALTH's Climate Change Program conducted a statewide vulnerability assessment to examine various demographic, social, and environmental factors. The study used 2010 Census data to include the following:

- Elderly Population
- Poverty and Median Household Income
- Educational Attainment
- Linguistic Isolation
- Average Daily Heat related hospital admissions
- Children
- Vehicle Access
- Immigrant Populations
- Percent of Children with an Asthma Claim
- Flood zones

ProvPlan developed a Social Vulnerability Index for the project, applying a numerical score to each category to help identify which Census tracts many be more vulnerable than others. This Index is a starting point, as we will conduct more detailed vulnerability analyses to examine specific climate exposures and health outcomes in the future.

FIGURE 5. SOCIAL VULNERABIILITY INDEX* BY CENSUS TRACT



*Additive index of percentile ranks across 8 dimensions of social vulnerability: elderly, children, poverty, income, vehicle access, educational attainment, immigrant populations, and linguistic isolation.
New Shoreham not drawn to scale.

Rhode Island State Plane Feet, NAD83
Data Sources: U.S. Census Bureau; Census 2010; Summary File 1. U.S. Census Bureau;
American Community Survey, 2007-2011 American Community Survey 5-Year Estimates.

Faces of climate change: Donna Marcaccio

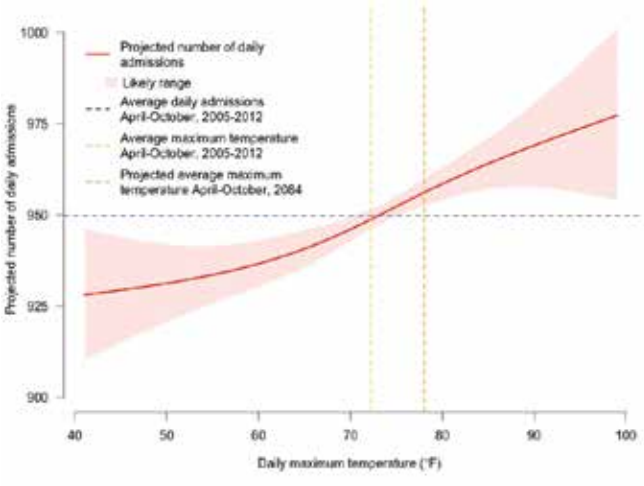
Donna Marcaccio has taught 3rd, 4th, and 5th grade special education for three years at Lillian Feinstein Elementary school in Providence. Donna recognized that her school was located in an urban heat island where summer temperatures were routinely 5° to 7°F hotter than nearby suburban areas (see: http://www.nasa.gov/topics/earth/features/heat-island-sprawl.html). Climate change will likely increase the heat island effect, exacerbating health impacts from heat and pollution associated with urban heat islands.

Donna saw that planting trees could be a cost-effective way to involve her students in countering the heat island effect. Lillian Feinstein participated in a tree-planting with the Providence Neighborhood Planting Program last year, and had the honor of planting the program's 10,000th tree outside of the school. Along with mitigating the urban heat island effect, the students were learning about their neighborhood and building community. "They got to see their community in a broader picture. This school is part of a community… and they all came out to help on this one day," remembers Marcaccio.

Climate Projections and Research

HEALTH and Brown University have partnered to explore the impact of increasing temperatures on health outcomes in Rhode Island, project future impacts of increasing temperatures, and to identify the groups most vulnerable to heat. . These studies support efforts to target heat-related education for susceptible groups and establish improved means of communicating warnings to widespread audiences.

FIGURE 6. PROJECTED NUMBER OF DAILY EMERGENCY DEPARTMENT ADMISSIONS IN RI BY MAXIMUM TEMPERATURE

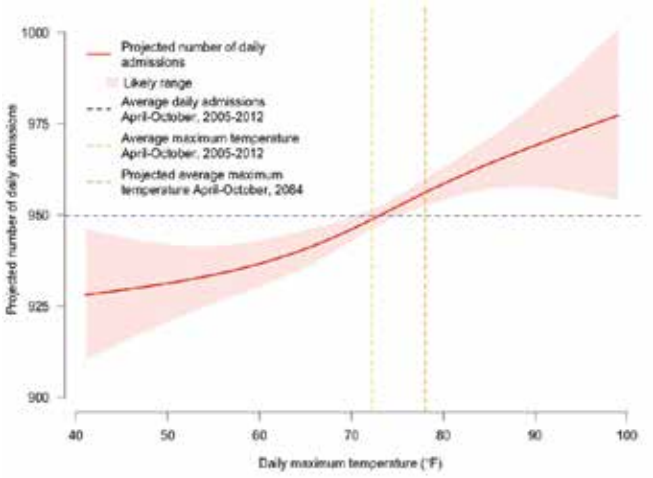


Graph depicting projected number of emergency department visits for all causes by daily maximum temperature

In the first phase of our partnership with Brown University's School of Public Health Department of Epidemiology, we researched the association between daily maximum temperature and emergency department visits in Rhode Island. Higher daily maximum temperatures in Rhode Island were significantly associated with higher numbers of emergency department visits. Projected emergency department visits for all causes steadily increased with rising temperature (Figure 6). The results have been adjusted for other factors potentially related to emergency department visits, including day of week, holidays, season, and air pollution.

We next considered whether these results were similar across people of different age groups. We found that the association between temperature and risk of emergency department visits was more pronounced among those under 18 years old and those over 65 years old and less pronounced among residents between 18 and 64 years old. Those aged 65 and over experienced the most pronounced increase in total emergency department visits with rising daily maximum temperature compared to other age groups. This confirms that these younger and older age groups are the most vulnerable to heat effects from climate change and is consistent with national data.

FIGURE 7. PROJECTED NUMBER OF HEAT-RELATED DEHYDRATION EMERGENCY DEPARTMENT ADMISSIONS



Graph depicting projected number of heat related dehydration emergency department admissions by maximum temperature

The relationship between temperature and hospital admissions varied when examining admissions specifically identified as related to heat and dehydration. Starting at around 75°F, excess emergency department visits increased rapidly with increasing maximum daily temperature (Figure 7). These increased admissions applied to all age groups, but notably the most affected demographic were those aged 18 to 64, the group that was least correlated with all-cause emergency department visits. Possible explanations for these findings will be explored in future studies. It is possible that the individuals admitted to hospitals specifically for heat-related illness or dehydration may be more likely to be working outdoors or performing physical activity in higher temperatures. Alternatively, heat-related illness may be under-diagnosed in other populations with pre-existing medical conditions. If heat –related illness or dehydration exacerbates pre-existing conditions like cardiovascular or renal disease, but is not diagnosed, this would dilute the strength of the effect between temperature and admissions specifically due to heat and dehydration for the youngest and oldest age groups. This suggests that improving diagnoses of heat-related illness and dehydration in those with pre-existing conditions will result in finding an even more robust relationship between hospitalizations and daily maximum temperature.

Working with our partner, TetraTech, we created climate models that projected future temperature increases due to climate change. These models offer 24 climate scenarios. Four global climate models were used to predict temperatures during three time periods and under two different greenhouse gas emissions scenarios.

What are emission scenarios?

Emissions scenarios describe future releases into the atmosphere of greenhouse gases and other pollutants, and include changes in land use and land cover. Each scenario is based on different assumptions about patterns of economic and population growth, technology development, and other factors. Because levels of future emissions are highly uncertain, these emissions scenarios provide alternative snapshots of how the future might unfold.

As shown in Table 1, our climate models predict that temperature would increase 1.6°F by 2022 and 5.7°F by 2084, resulting in 378 and 1372 more emergency department visits due to these higher temperatures. We include projected admissions for all causes, as well as those directly attributable to heat and dehydration.

TABLE 1. PROJECTED INCREASES IN EMERGENCY DEPARTMENT VISITS IN RHODE ISLAND DUE TO HIGHER TEMPERATURE, APRIL - OCTOBER

Year	2022	2052	2084
Predicted increase in total emergency department admissions (excluding heat and dehydration as underlying cause)	99	219	358
Predicted increase in admissions due to heat and dehydration	378	837	1,372

*Assuming stable populations

Our findings help to illustrate that climate change's warming effects have the potential to significantly increase public health risks in Rhode Island, leading to more hospital admissions and illness. For instance, if the associations that we have found remain constant, we can now predict that, if the temperature rises to 90°F due to climate change on a normally 80°F summer day, this could result in a 60% increase in hospitalizations due to heat and dehydration amongst those aged between 18 and 64.

Our research partnership with Brown University is now expanding to take a more in-depth look into the impacts of heat and specific social and geographic vulnerabilities in Rhode Island. To strengthen our research, we are partnering with the CDC BRACE programs in Maine, New Hampshire, and Massachusetts. These partnerships will help us to compare our findings, develop consistent methodologies, and collaborate on adaptation strategies for our individual states and the region.

Case Study

Lack of preparedness in addressing the dangers of heat can lead to disastrous consequences. In the 1995 Chicago heat wave, over a period of 17 days, temperatures increased from a normal 63-84°F temperature range to an 83-104°F range. This event resulted in approximately 465 heat-related excess deaths in the Chicago area. Heat-related deaths are preventable if adequate response plans and response capacity are in place to recognize a heat wave as a public health emergency.[36] Although the city had generated preparedness plans for other weather-related emergencies, such as blizzards or hurricanes, their failure to develop one for heat waves resulted in limited access to resources when disaster struck. The National Weather Service had predicted the heat wave well in advance and broadcasted their warnings across the state, however, most citizens considered heat waves to be inconveniencing rather than deadly. Public health officials and other responders did not effectively convey the potential consequences of a heat wave to Chicago residents. In addition, city officials underestimated the vulnerability of isolated elderly popula-

tion. These people not only found it more challenging to physically adapt to the higher temperatures, but they also were less informed about appropriate measures to take to decrease their susceptibility.15 Identifying vulnerable populations and targeting public health education campaigns to these populations is a necessary component of emergency response plans.

Best Practices

As the issue of increasing temperature and health impacts is one that is faced globally, we are looking to others to examine best practices and solutions. We have included some examples below.

North Carolina

The North Carolina Department of Health hosted an educational campaign on heat-related illness and heat waves during the peak of summer. In this way, they sought to educate younger, vulnerable populations by distributing and displaying posters in high schools within the state. The posters were fact sheets containing a list of signs and prevention methods of heat-related illness. This not only informed students who were susceptible due to their age but also those more likely to be physically active and unaware of the dangers of heat waves.[37]

Philadelphia, Pennsylvania

The City of Philadelphia has been a leader and innovator in using green infrastructure throughout its neighborhoods as a technique to help manage stormwater, while at the same time generating a broad and valuable array of environmental, public health, and social benefits. A 2009 a study conducted for the Philadelphia Water Department's Green Streets program found that their plans to incorporate green infrastructure would actually reduce heat stress-related fatalities in the City during extreme heat wave events. City-wide, they estimated that 196 premature fatalities would be avoided over the 40-year project planning horizon.[38]

New York, New York

PlanNYC is New York City's plan to enhance resiliency to heat-related illness, by building community response teams to strengthen social networks that reduce the vulnerability of isolated individuals.[39] In addition, New York City implemented a CoolRoofs program to install reflective surfaces or paint roofs white. This reduces the heat island effect by cooling buildings, reduces the need for air conditioning, and mitigates energy consumption that contributes to global climate change.[40]

San Francisco, California

San Francisco's Department of Public Health conducted research on the relationships between temperature, hospitalizations, and emergency department visits to assess the health effects of extreme heat. Their findings that, as heat increases, illnesses also consistently increase, as measured by the number of emergency department visits and hospitalizations.[41]

Chicago, Illinois

To reduce the impacts of the heat island effect and prevent heat-related illness and mortality, the City of Chicago has planted over 600,000 trees in the city since 1991, installed 4 million square feet of green roofs on 300 buildings in 2010, and mapped urban hotspots to allow developers to plan future projects appropriately.[42,43]

Current and Future Projects

Health's Climate Change program is collaborating with local community partners to craft response plans for heat emergencies that include adaption strategies for vulnerable populations and communication methods to engage younger and older demographics, and others identified as vulnerable. Listed below are examples of HEALTH's heat related projects and initiatives:

TRI Lab- Climate Change and Environmental Justice in Providence

The Climate Change and Environmental Justice (CCEJ) Lab will investigate ways to reduce the climate change-related public health risks to individuals in three targeted neighborhoods in Providence and increase the capacities of these neighborhoods to respond to climate change threats. Through this partnership with Brown University faculty and students, HEALTH will explore the development of green infrastructure in our cities and other urban design solutions to mitigate the urban heat island effect and better prepare and recover from extreme weather events and power outages.

Senior Resiliency Project

The Senior Resiliency Project is funded through a grant from HUD and the RI Office of Housing and Community Development, as a part of the state's Community Development Block Grant, Disaster Recovery (CDBG-DR) action plan.

In partnership with the Division of Elderly Affairs, the Lieutenant Governor's Office, Brown University, and other community partners, we are working to assist long-term care facilities, senior housing complexes, and older adults prepare for weather related emergencies, such as extreme heat and power outages. Our team of partners, stakeholders, and a qualified vendor will support our pilot sites to prepare for these scenarios through intensive and site-specific energy resiliency audits and the development of all-hazards emergency plans that emphasize sheltering in place.

Regional Heat Warning Study and National Weather Service Project

Working with our regional partners within the CDC BRACE program, we are exploring health data driven standards for heat warnings and communications. Our research with Brown University will support this process and collaboration with the National Weather Service will help us to improve our warning systems in Rhode Island and throughout New England.

HEALTH Heat Response Plan

In partnership with HEALTH's Center for Emergency Preparedness and Response (CEPR), the Climate Change Program is developing an internal Heat Response Plan. The plan will include guidance for outside partners and agencies, communications tools and public service announcements, as well as standards for early and immediate warning systems. The plan will help unify the State's heat response messaging and actions.

Heat Documentation- RI Hospitals

We look to improve surveillance of heat-related illness through better identification and documentation of heat injury at hospital admission. The step will be to develop a relationship with the clinical documentation specialists in Rhode Island hospitals. Enlisting support of hospital staff is essential to improvements in recognition of heat as an underlying and contributing cause to morbidity and mortality. Improving admissions data will help us quantify the health impacts of heat and gain a better understanding of the importance of co-morbidities and other factors related to vulnerability.

iTree Canopy Cover Assessment and Tree Benefits Analysis Report

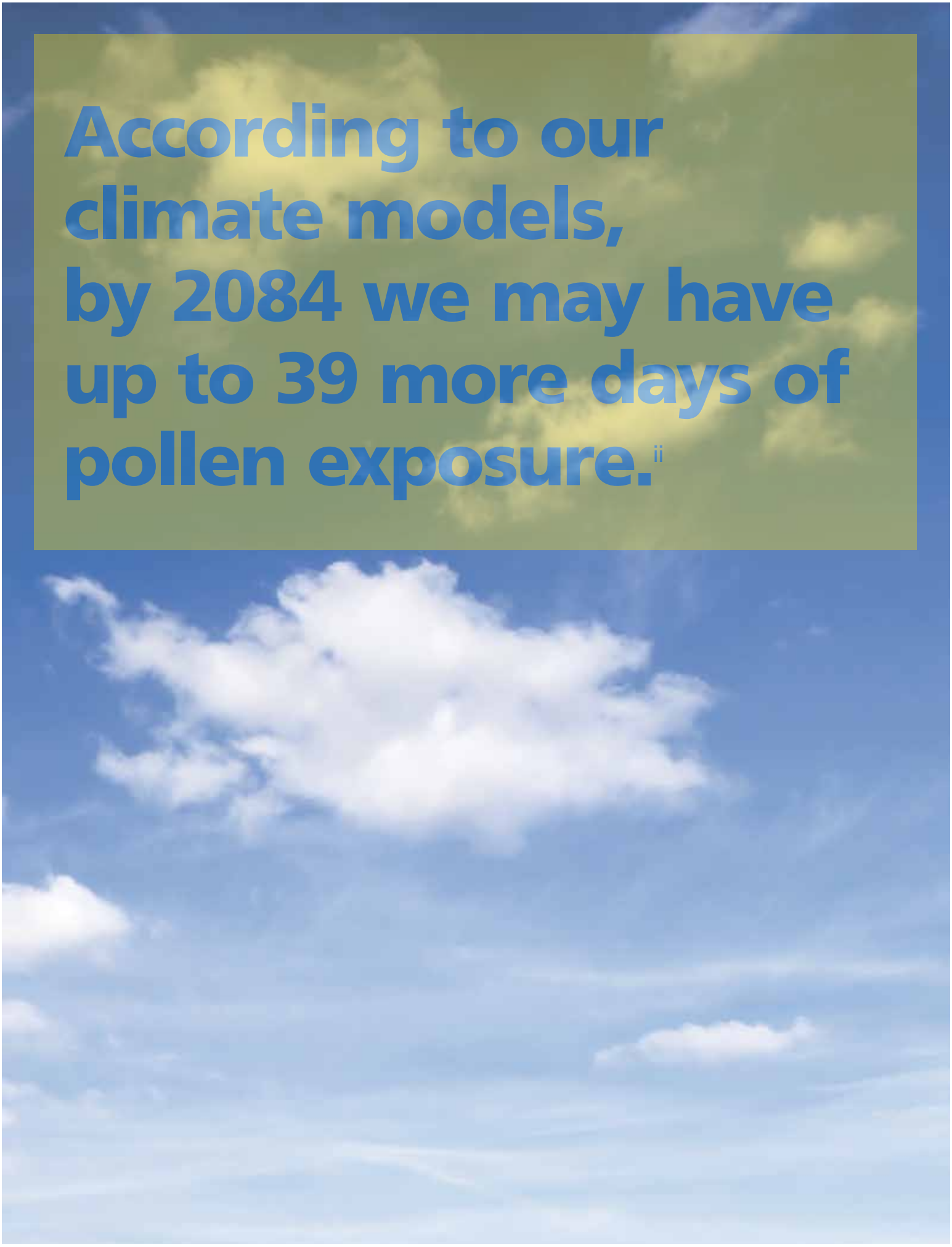
In June 2014 the Rhode Island Division of Forest Environment produced the iTree Canopy Cover Assessment and Tree Benefits Analysis Report. This report produced database of the tree canopy coverage for each Rhode Island municipality and their attributed myriad of benefits. The Division of Forest Environment is working with HEALTH to cross reference this database with Census data to allow the municipalities with the lowest canopy coverage and highest poverty rates to be identified.

Many of our potential solutions are both mitigative and adaptive, in that they limit the magnitude of climate change as well as reduce residents' vulnerability to potential impacts.[44] For example, planting trees is an adaptive strategy to provide cooling via shade and is a mitigative strategy for reducing carbon dioxide which is absorbed during tree growth. In contrast, strategies to expand access to air conditioning, while of benefit for particularly susceptible populations, increases energy use, further contributing to climate change. Therefore, as we develop programs and policies, we seek a systems-level approach to maximize both the short and long term benefits. Establishing centralized cooling centers for anyone lacking access to air conditioning can provide short-term relief from the heat, and can also encourage social cohesion, reducing the adverse effects of social isolation.[45,46] As we continue to develop policies and strategies for climate change adaptation, we will prioritize those measures which also mitigate climate change.

Westminster Street, Providence

Next Steps

To expand upon our preliminary research findings, we will work with our regional partners, to identify individual or neighborhood characteristics that place residents at greater risk of heat-related health effects. Individual characteristics to be examined include age, race, and comorbidities such as diabetes or respiratory disease. Neighborhood characteristics that will be assessed include markers of neighborhood poverty, measures of the heat island effect, proximity to the coast, and amount of local green space. This work will also include refinements to how to estimate mean or maximum temperature. Instead of relying on data from a limited number of local weather stations, in the future we hope to use data from satellites to identify urban heat islands and more precisely estimate individuals' exposures to heat. In addition to developing regional collaborative research methodologies, we will be expanding our local partnerships to identify opportunities for strategy development, outreach, and education. We look to prevent heat illness by developing targeted and coordinated adaptation strategies with community partners.


According to our climate models, by 2084 we may have up to 39 more days of pollen exposure.[ii]

AIR QUALITY

Health Effects

Almost half of Americans live in counties impacted by air quality that routinely fails to meet national ambient air quality standards.[47] Most of Rhode Island received an air quality rating of C or below by the American Lung Association,[48] indicating a significant number of days with high levels of air pollution. Air pollution can result in a variety of health issues, such as damage to lung tissue, exacerbated respiratory disease, emergence of respiratory symptoms, reduced lung function, heart attacks, stroke lower cognitive function, cancer, and death. Climate change and air quality are closely interlinked. Increasing temperatures are likely to magnify air pollution's detrimental health outcomes.

Air pollution can result in a variety of health issues, such as damage to lung tissue, exacerbated respiratory disease, emergence of respiratory symptoms, reduced lung function, heart attacks, stroke lower cognitive function, cancer, and death.

Air quality assessments often include measurements of the concentrations of ozone, fine particulate matter, and allergens, which all independently contribute to various negative health consequences. For instance, ground-level ozone, which is one of the pollutants in smog, can limit lung functionality, aggravate respiratory disease, and induce coughing and shortness of breath.[49] As a result, increased levels of ozone have been associated with higher rates of hospital admissions, respiratory infections, and potentially the development of asthma.[50] Because ozone forms in the presence of heat and sunlight, climate change is likely to increase ozone formation in the atmosphere and lead to lower air quality in vulnerable regions.[51] These relationships perpetuate a cycle of positive feedback effects with potentially dangerous consequences.

Fine particulate matter is also a component of smog and is comprised of small particles of soot, smoke or other contaminants.[52] Fine particulate matter forms predominantly as the result of combustion processes. It is found in power plant emissions, motor vehicle exhaust and smoke from wildfires which are increasing with the higher temperatures associated with climate change.[53] Exacerbating heart and lung conditions, fine particulate matter causes increases in medication use, hospital admissions, and premature deaths from heart disease and stroke. Although the specific relationship between climate change and fine particulate matter is complex—increased rainfall could clean the air of pollutants while elevated risk of wildfire could lead to higher particulate matter concentrations—the formation of particulate matter is partially dependent on temperature and humidity.[54,55] Consequently, it is probable that climate change will increase fine particulate pollutants in the atmosphere.

Allergens including pollen, mold, and dust, are all expected to increase due to climate change. Elevated levels of carbon dioxide may contribute to plant growth and pollen production, as well. The growth of mold, both outdoors and indoors, increases with heat and humidity. Indoor mold problems are a particular problem after flooding. As part of a nationwide study, it was found that 23% of 2,600 examined Rhode Island houses reported having at least traces of dampness or mold.[56] With flooding risk predicted to increase with more extreme precipitation and sea-level rise due to climate change, mold presents a significant problem for Ocean State inhabitants in the present and future. These allergens present similar health risks. These allergens can cause allergic rhinitis, commonly known as hay fever, and thus are associated with sneezing, stuffy or runny nose, and itchy throat, nose, eyes, or ears. Furthermore, they can aggravate respiratory diseases such as asthma and chronic obstructive pulmonary disease. As a result, allergic diseases rank as the sixth leading cause of chronic disease in the United States.[57]

Climate Projections

According to our models, the onset of spring bloom may occur up to 21 days earlier in 2084, relative to present conditions, and the first frost may occur up to 18 days later (Table 2).[58] This extended growing season means a longer periods of pollen exposure, and, coupled with increased flooding risk, mold exposure, as well. Therefore, projections indicate a possible lengthening of the period of high aeroallergen concentrations up to 39 days, resulting in greater exposure to allergens and higher rates of illness. Because higher temperatures increase the rates of formation of ozone and fine particulate matter, the combined impacts of climate change on air quality will likely have significant impacts on respiratory and cardiovascular disease.

TABLE 2. LENGTH OF AEROALLERGEN PRODUCTION SEASON IN NUMBER OF DAYS AT THE MEDIAN OF CLIMATE MODEL PROJECTIONS

TIME HORIZON	TREE BLOOM	FIRST FREEZE	SEASON LENGTH
1978 - 2007 baseline	May 3	October 25	177
2022	April 27	November 3	190
2052	April 20	November 9	203
2084	April 12	November 12	214

Vulnerable Populations

Ozone, fine particulate matter, pollen, and mold all influence air quality, but some air pollutants have higher concentrations in different environments, such as indoor versus outdoor, rural or urban. Subsequently, people can be more vulnerable to different pollutants depending on where they live or work. For example, outdoor workers and people who exercise outside are more vulnerable to the health effects of outdoor air pollution and may be at higher risk for lung damage and irritation.[9] On the other hand, the elderly usually spend more time indoors and consequently are more exposed to indoor air pollutants.

Two groups considered especially vulnerable are children and older adults. Older adults have increased suseptibility to both indoor and outdoor air pollution due to decreased immune and respiratory functionality, resulting from normal aging, as well as a relatively greater burden of chronic disease. Therefore, studies have found air pollution leads to greater rates of asthma and chronic obstructive pulmonary disease in those aged over 65 years.[59] Children are also likely to be more susceptible to poor air quality. Children's bodies are still developing. Air pollutants can impact the development of their brain, lungs, and immune system. Furthermore, children under six years old have especially permeable linings in their respiratory tract and have a higher ratio of surface area to body weight compared to adults, meaning they breathe proportionally more air than older counterparts. These factors have been shown to lead to both short- and long-term effects, including the development of asthma and other chronic respiratory diseases.[60]

People who already have asthma, allergies, or other respiratory diseases also face increased risk when exposed to air pollutants, since reduced air quality can heighten sensitivity to allergens and impair lung function. Exposure to air pollutants can accordingly trigger asthma attacks or exacerbate respiratory issues.[61] Because 82,000 adults in Rhode Island reported having asthma in 2009, this respiratory disease presents a major problem to the state.[62] Other pre-exisiting ailments can also compromise the body's ability to resist exposure effects, such as diabetes and cardiorespiratory diseases.[63]

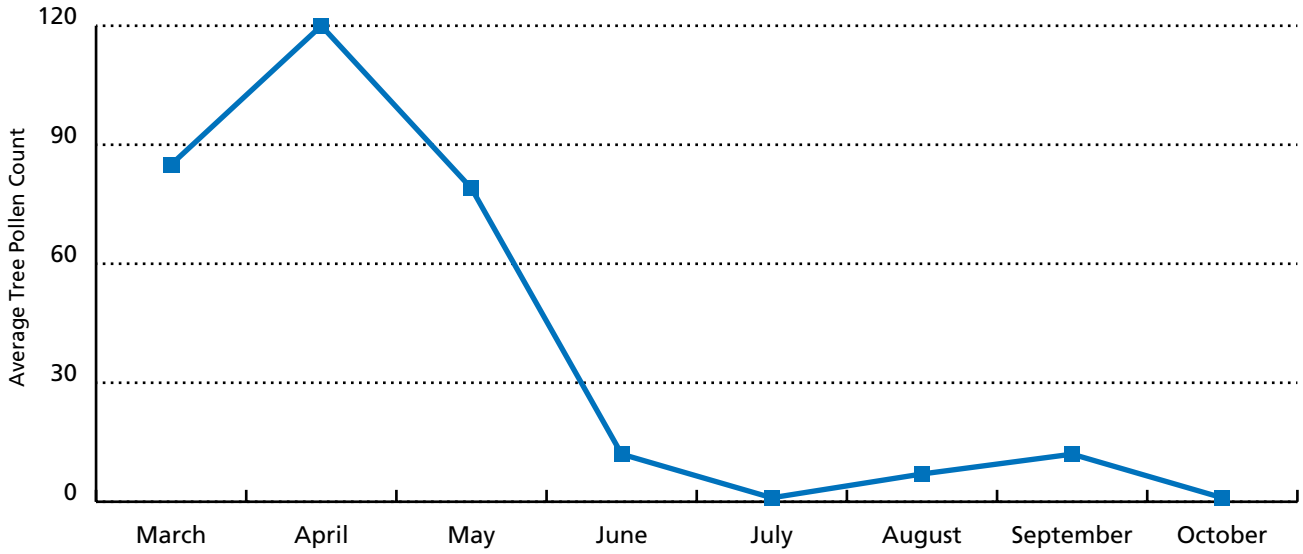
Due to higher levels of traffic-related pollution and, more generally, the mixing of combustion products, cities tend to have worse air quality than more rural areas.[64] As a result, urban residents are more susceptible to the health effects of poor air quality. Many minority and low-socioeconomic populations live in urban communities that are faced with especially high levels of air pollution.[65] These disadvantaged groups often have limited capacity to reduce their exposure to air pollution, tending to have high-exposure jobs or residing in poor-quality housing that do not protect against allergens or ambient pollution. In addition, they often have lower rates of education and more frequently engage in behaviors that elevate risk, such as eating poorly and increasing indoor pollution through smoking.[20]

Rhode Island faces these challenges statewide. There is nowhere in the State to escape exposure to ragweed pollen. Rhode Island's air quality alerts for elevated levels of ozone or particulate matter are issued for the entire State, although air pollutants tend to have higher concentrations in urban areas where more than 90% of Rhode Island residents live.[66] Consequently, Rhode Island is especially vulnerable to the negative health outcomes of reduced air quality.

Research

In partnership with Brown University's School of Public Health Department of Epidemiology, we completed a small-scale research study analyzing pollen data collected from the Allergy and Asthma Center of Providence. These data had been hand-recorded from 2008 to 2013 during spring, summer, and fall seasons and includes the pollen count from many species of trees and grasses. We digitized this data in order to analyze the association between pollen counts and other factors, such as temperature or asthma hospital admissions. Our preliminary research has pointed to the consistent expected pattern of highest pollen counts during March through May, peaking in April particularly, and then cycling downward as the year progresses before reaching almost zero after June. With our models predicting that this pollen count peak will be extended, climate change most likely will lead to greater rates of respiratory irritation and disease in the Rhode Island population.

FIGURE 8. AVERAGE POLLEN COUNT BY MONTH IN PROVIDENCE, 2012



Our preliminary analyses suggest a relationship between asthma admissions and pollen count. However, the collected data has many limitations that reduce the reliability of our results. Pollen count was not collected daily, so on certain entries we had to approximate the number of pollen grains over 24 hours by dividing the recorded measurement by the number of days since the last measurement had been taken. Some years had more data entries than others; for instance, 2010 only had 19 measurements whereas 2012 had 140 days taken into account. Also, rainfall and equipment malfunctions interfered with data collection. Overall, we need much more consistent and frequent pollen surveillance over areas throughout Rhode Island to enhance the robustness of our results and find strong evidence of the impacts of these allergens on human health.

Best Practices and Solutions

By looking at other states' efforts to address air quality and climate change, we can begin to consider what practices may best meet the needs of Rhode Island residents. We have included some examples below.

Florida

Florida has developed a climate adaptation strategy that focuses on air quality as a function of climate, establishing air quality standards and policies that incorporate future risks from climate change. In addition, it is conducting research that will improve projections of potential public health outcomes by examining how extreme heat waves can magnify existing urban air pollution.[67]

New Hampshire

The New Hampshire Department of Environmental Services has bolstered the capacity of its local emergency services in order to respond more efficiently on days with worsened air quality from higher temperatures.[68] It is also taking steps that will reduce traffic emissions by targeting automobile fuel efficiency, improving traffic flow, and encouraging greater use of public transportation.[69]

Atlanta, Georgia

Created by the Georgia Department of Transportation and The Clean Air Campaign, Georgia Commute Options offers monetary incentives for drivers to form groups when driving to and from work. It also manages programs that will find nearby carpool partners and set up these arrangements for participants. This encourages carpooling and thus reduces traffic pollution, a significant problem in Atlanta. By logging their miles, carpoolers can receive gas cards and other forms of financial compensation. More than 85,000 commuters have registered so far.[70]

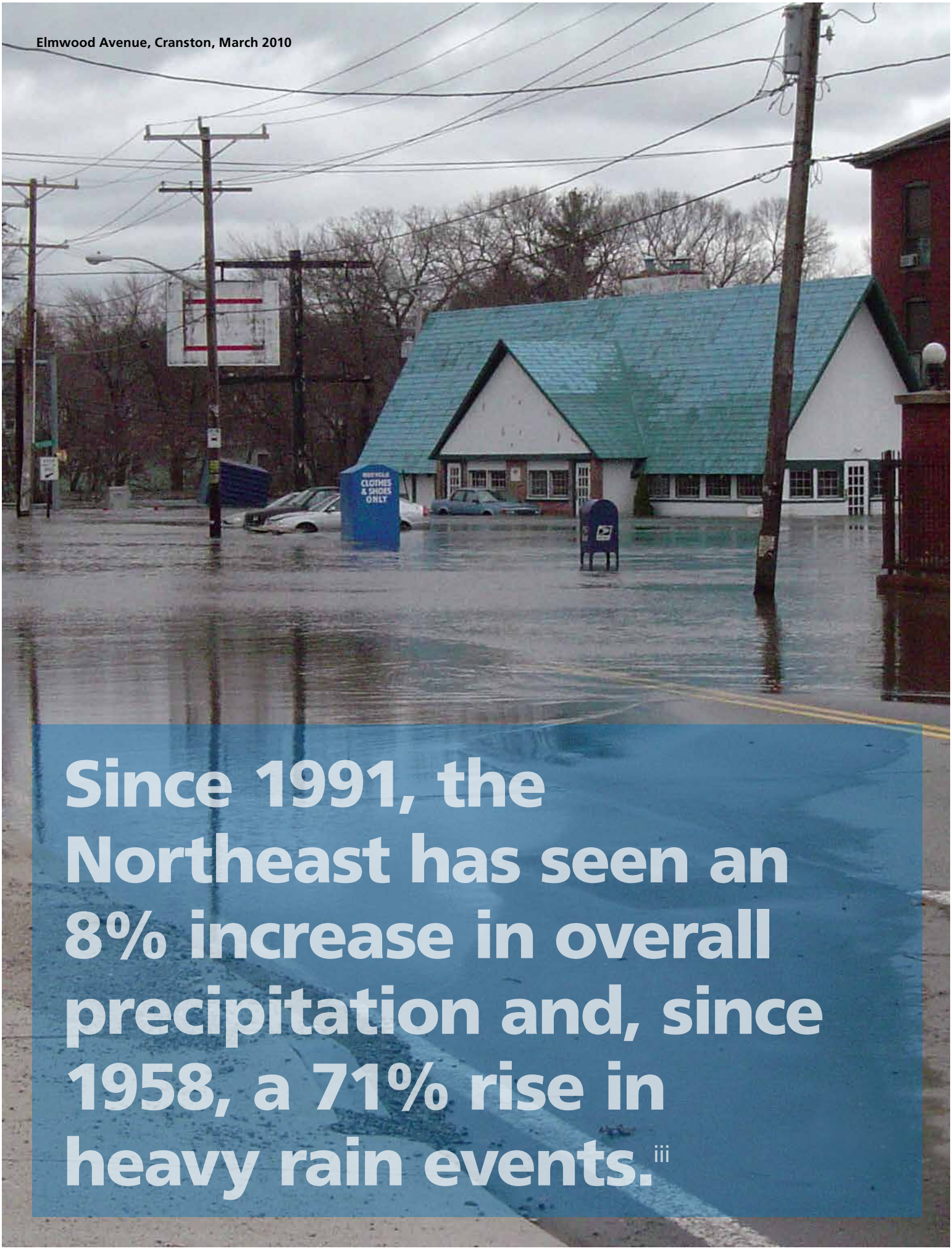
Milwaukee, Wisconsin

The City of Milwaukee has planned to improve air quality by increasing tree canopy cover, as urban trees have the potential to remove large amounts of air pollution,[71] and expanding cogeneration of power production. Wisconsin has increased outreach regarding its air quality warning system to specific groups, such as school nurses, daycare centers, nursing homes, summer camps, and local public health departments, in order to more effectively access vulnerable populations.[72]

Next Steps

Through our partnership with Brown University, we will be conducting further research on the relationships between air quality, climate change, and health impacts in Rhode Island. For instance, we will evaluate whether the adverse health effects of air pollution are more pronounced on hotter days versus cooler days. Evidence from other geographic locations suggests that this could be the case, but no one has tested this hypothesis specifically in Rhode Island. If ozone is more strongly related to hospital emergency department visits on warmer days, then hotter summer time temperatures would be expected to result in more adverse health impacts from air pollution. Due to the many health impacts related to air pollution we are working to expand our research and implement solutions that can most effectively protect Rhode Island residents' health.

National Grid, Providence



Elmwood Avenue, Cranston, March 2010

Since 1991, the Northeast has seen an 8% increase in overall precipitation and, since 1958, a 71% rise in heavy rain events.[iii]

EXTREME WEATHER

Rhode Island weather is already impacted by climate change. Over the past 80 years, trends are evident in increasing temperature, precipitation and the frequency of intense rainfall events and storms. Since 2010, the federal government has declared a Presidential Disaster in Rhode Island four times - for the 2010 spring floods, for Hurricane Irene in 2011, for Hurricane Sandy in 2012 and finally for winter storm Nemo in 2013.[73] These events shocked many residents – 2010 was the first time Rhode Island had experienced a Presidential Disaster Declaration.

A Presidential Disaster Declaration is an action by the President, pursuant to the Compact of Free Association, to make U.S. federal funding available for emergency relief and reconstruction assistance.

Health Effects

Natural disasters have a number of public health implications that vary depending on the nature of the event and the characteristics of the affected population. The health effects of disasters extend beyond the immediate injuries and trauma of a disaster, affecting communities long after the event with issues associated with mental health and population displacement. The growing influence of natural disasters such as storms, hurricanes, and floods may increase the burden of these health effects worldwide.

Floods are the most frequent natural disaster in the United States. Seventy-five percent of national disaster declarations arise from flooding, and flood events result in more casualties than any other natural disaster.[74,75] In the U.S., between 47 and 146 deaths occur annually due to floods.[76] Drownings in flash floods account for the majority of the fatalities that follow a flood event. Other common causes of flood-related mortality are hypothermia, trauma, drowning, and a combination of these.[77] Although concern about outbreaks of communicable diseases often arises after a flooding event, research suggests that such outbreaks occur only rarely.[78] Rainfall and other climatic factors affect the population dynamics of several vectors that play a role in human disease. Flooding may leave behind standing water that can facilitate the proliferation of mosquito vectors, increasing the risk of arbovirus transmission (West Nile Virus, Eastern equine encephalitis virus.[79]

A 2010 report on vulnerability in Rhode Island found that the additional hurricane risk associated with the climate change resulting from a high-emissions pathway could increase hurricane damages by $2 to $6 billion.[80] The human health costs of increasing hurricane intensity and frequency are difficult to quantify. Although the number and causes of hurricane fatalities differ with characteristics of the

Kinsley Avenue, Providence, March 2010

affected populations, patterns of hurricane deaths are similar around the world. Nine out of ten hurricane deaths are due to drowning, especially during rapid-rise flooding caused by the hurricane. Other significant causes of hurricane morbidity and mortality are crushing under collapsed structures and blunt and penetrating trauma from debris.[81] Certain populations are affected more acutely by health risks that arise during and after a hurricane. People who live in mobile homes, for example, may be more likely to receive the most severe injuries during a hurricane.[82] Additionally, health risks do not necessarily diminish after the hurricane is over. A significant percentage of morbidity occurs during the cleanup after a disaster; injuries from chainsaw wounds and electrocution are not uncommon after a hurricane.[83]

While the direct effects of hurricanes and storms may be the most visible, the indirect effects of these events are also devastating. Storms and flooding can disrupt sewage and sanitation systems, increasing the risk of infectious disease transmission.[84] Additionally, flooding and storms can compromise agriculture and chemical repositories, resulting in chemical contamination of water, air, and soil. During the March 2010 floods, the Rhode Island Department of Environmental Management responded to 179 incidents of hazardous material contamination. Most of these incidents were caused by compromised home heating tanks.[85] Fires from igniting fuel storage may also

Residential Mold

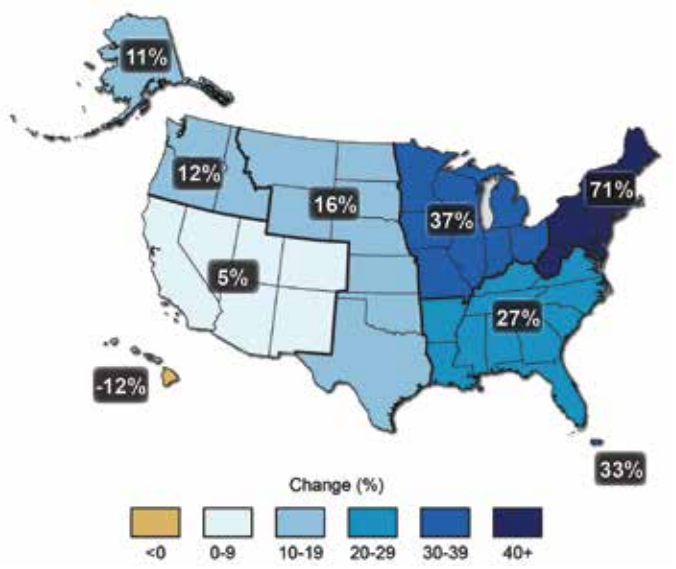
pose an injury risk following a flood or storm. Loss of electricity can pose a number of public health risks. For example, lack of adequate refrigeration can jeopardize food stores and increase the risk of food-borne illness. Hypothermia or hyperthermia may also be a concern for people, especially the elderly, during a power outage. The extensive water damage caused by a hurricane can also pose a health risk. After extensive water damage, mold may develop in damaged structures or items if not quickly and thoroughly dried. Exposure to molds can result in a number of health complications, such as skin irritation and respiratory problems. Displacement after a disaster may also pose physical and health risks. After a flood or storm, crowding of displaced people in shelters increases the probability of disease transmission.

Climate Projections

Extreme weather events like Hurricane Sandy and the floods of 2010 promise to become more frequent and devastating in the coming years. Models indicate that climate change will increase the frequency and intensity of extreme weather events, such as heavy precipitation, storms and hurricanes.[86,87] Winter storms, flooding, and hurricanes are the most common natural disasters in Rhode Island, but tornadoes and earthquakes have also affected the state.

While projections for extreme events are uncertain, it is helpful to use recent trends to see how climate change has already impacted us and the direction we are headed. Figure 9 shows the percent increase of extreme precipitation events in the US from 1958 to 2012. The Northeast has seen the most dramatic change in the US and these trends are projected to continue into the future. Changes in extreme precipitation and development pose threats to areas of Rhode Island that have never been considered flood zones. Since the 1950's, large areas throughout the state have been developed and hardened. Open areas that could infiltrate large amounts of stormwater into the ground, are now paved over as highways, parking lots, malls, etc. The floods of 2010, although devastating, helped many communities take action and recognize that development practices and stormwater management must be adapted. As research and modeling related to storms, floods, and precipitation continue to improve and provide us new guidance, it will be crucial to use our recent experiences and trends to inform resilience planning.

FIGURE 9. OBSERVED CHANGE IN VERY HEAVY PRECIPITATION



The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. These trends are larger than natural variations for the Northeast, Midwest, Puerto Rico, Southeast, Great Plains, and Alaska. The trends are not larger than natural variations for the Southwest, Hawai'i, and the Northwest. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: updated from Karl et al. 2009).

Vulnerable Populations

Several populations in Rhode Island may be particularly vulnerable to storms and floods. The elderly, particularly those with limited mobility, may be unable to move from danger or recover from an event. The elderly accounted for seventy percent of Hurricane Katrina deaths,[88] and more than half of the people who were killed during Hurricane Sandy were older than 65.[89] Children are also very vulnerable to the effects of storms and disasters, as they are dependent on their parents for evacuation and may be more sensitive to the stress of a disaster and its aftermath.[90] The particular needs of these populations should be taken into account as disaster preparedness methods are implemented. Because of their unique vulnerabilities, building social cohesion within elderly communities and reducing social isolation should be a priority.[91] Other populations within Rhode Island may be disproportionately affected by storms and disasters. Populations who live in marginal socio-economic situations may bear a greater burden during the storm or disaster and may be unable to access a safety net following the event. For example, disabled individuals are particularly vulnerable during storms and disasters.[92] Additionally, certain communities are more vulnerable geographically. A recent Brown University report notes that low-income individuals are more likely to reside on property that lies on a floodplain.[93] Because they are more vulnerable geographically, the impact of the storm or disaster may be greater in these communities. Low-income groups may also find it more difficult to recover from a storm or disaster. A study of post-Katrina New Orleans concluded that, although communities across all income brackets were affected by the storm damage, higher-income groups were better equipped to respond to the disaster and cope with the aftermath.[94]

Faces of climate change: Todd Manni

Todd Manni knows emergencies. "I was born into public safety," he remembers. "I should have been a 3rd generation police officer, but I was bit by the disaster bug." He has served for four years as the Emergency Medical Services Program Coordinator at the Rhode Island Department of Health, and he works part-time as the Smithfield Emergency Management Director.

The increased risk of climate-driven disasters is necessitating a response from emergency management agencies across the world. In Rhode Island, emergency management professionals are taking climate change seriously. "It's got my undivided attention and concern," he says.

"Climate change is changing our focus in emergency management and in emergency planning…we need to be looking at this with a different perspective," Manni says. "We need to create a culture of emergency preparedness."

Case Study

The New England Climate Adaptation Project (NECAP)– a combined effort of the Massachusetts Institute of Technology Science Impact Collaborative and the Consensus Building Institute that was funded through the National Estuarine Research Reserve System's Science Collaborative – has focused on Cranston, RI and the communities of Wells, ME; Dover, NH; and Barnstable, MA. The project assessed local climate change risks, identified key challenges and opportunities for adaptation, and tested the use of role-play simulations as a means to educate the public about climate change threats and to help communities explore ways of decreasing their vulnerability and enhancing their resilience to climate change impacts. "Our intent is on helping communities move forward on difficult problems that require a lot of voices to come together," said Carri Hulet of the Consensus Building Institute.

Cranston's experience in the spring 2010 floods was one of the reasons the city was chosen to be a part of the project. The city has made tough decisions in the past few years to address flood risks. Through buy-out programs, the city has been able to purchase and demolish 7 houses in vulnerable areas and is continuing to develop adaptation strategies to prepare for the future. Green infrastructure, traditional stormwater management and hardening of surfaces are among some of the solutions being considered.

"This is really about doing better planning today," said Danya Rumore, a doctoral candidate and project manager with the New England Climate Adaptation Project, during a climate change presentation and workshop at Cranston City Hall. "You're going to feel impacts. It's a global issue with local effects … We don't know exactly what's coming, so let's plan to be adaptable."

Wellington Avenue, Cranston, March 2010

Current Projects

Rhode Island has responded to increasing storm and disaster risk by implementing interventions designed to increase resilience to natural disasters and support vulnerable populations. Projects that have already been mentioned include our TRI Lab partnership with Brown University and out Senior Resiliency Project. Other partnerships and projects are underway to help us address extreme weather and emergency preparedness. Highlights include:

Natural Disaster-related morbidity and mortality tracking

The RI Department of Health's Center of Emergency Preparedness and Response (CEPR) is tracking natural disaster-related injuries and deaths in partnership with RI hospitals. During events, RI hospitals report to CEPR how many death or injuries have occurred due to the extreme event. Additional information is provided to clarify the type of injury that occurred.

Special Needs Registry

The Rhode Island Department of Health and the Rhode Island Emergency Management Agency (RIEMA) have joined together to develop a registry for Rhode Islanders with disabilities, chronic conditions, and other special healthcare needs. This system is designed to identify individuals who may require special assistance during emergencies. Enrollment in the Registry does not guarantee assistance, but allows first responders to appropriately plan for, prepare for, and respond to the needs of the community.

Emergency Preparedness Workshops

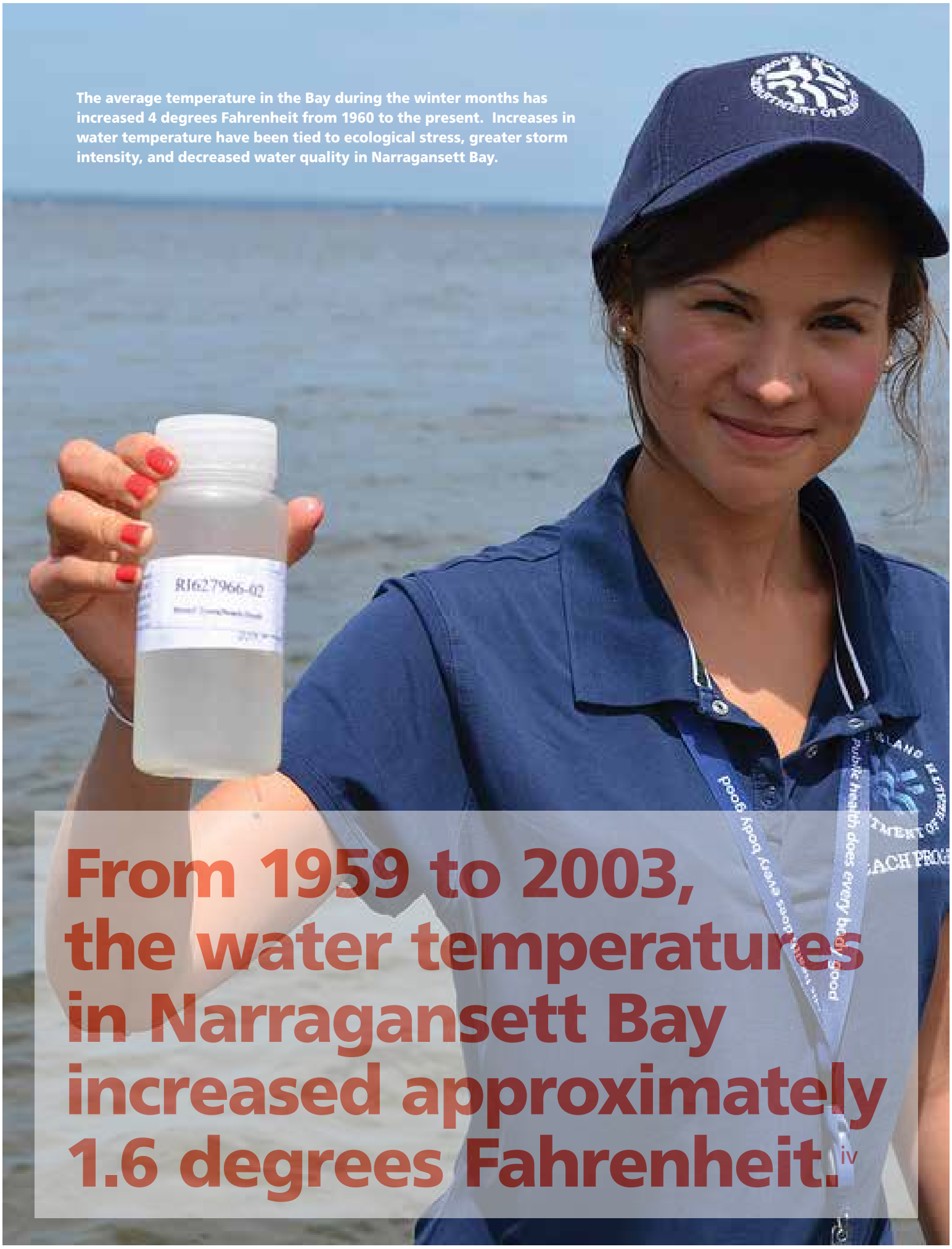
The Rhode Island Department of Health is offering emergency preparedness workshops for the public and specific vulnerable groups, such as people with disabilities. Workshops were held throughout the spring of 2014 in various communities across RI. Participants learned about common weather emergencies, climate change risks, and ways to become personally prepared. The workshops were co-sponsored by NOAA, the National Weather Service, and the Rhode Island Parent Information Network.

Disaster Aftermath: Are you Ready (from our OSHA 21(d) Consultation Program)

Our OSHA 21(d) Consultation Program offered special training for nursing homes and assisted living facilities to address necessary information to train and prepare employees for safe clean-up operations after natural disasters like hurricanes and snowstorms. The training covered: employers' responsibilities during clean-up and recovery operations, how to safely and properly prepare employees for clean-up operations, and how to identify potential hazards. Over 80 long-term care facilities from around the state participated.

Next Steps

HEALTH and our partners across Rhode Island are making strides in emergency preparedness, but our future approaches must account for the climate-driven increase in the frequency and intensity of natural disasters. Last winter, a series of icy storms depleted road salt supplies in many states. By the beginning of March, Rhode Island experienced a severe shortage of salt, leaving many local roads unsafe to travel. Emergency management agencies and the public health community can no longer approach storms and disasters as isolated events. Instead, disaster management must incorporate consideration of climate change into every stage of the disaster preparedness process.[95] Through coordinated policy and program development, our program and the many climate resiliency efforts across the state will help to mainstream these types of climate change considerations into disaster preparedness and every day planning.



The average temperature in the Bay during the winter months has increased 4 degrees Fahrenheit from 1960 to the present. Increases in water temperature have been tied to ecological stress, greater storm intensity, and decreased water quality in Narragansett Bay.

From 1959 to 2003, the water temperatures in Narragansett Bay increased approximately 1.6 degrees Fahrenheit.[iv]

WATER QUALITY

Here in the Ocean State, our salt and fresh water bodies play an important role for our economy, tourism, and the well-being of our residents. We enjoy and appreciate our waters and beaches for consumption, swimming, boating, fishing, aquaculture, and more. Unfortunately, climate change threatens our ability to safely consume, access, and utilize these resources as temperatures increase and as we see more intense rain events. From 1959 to 2003, the water temperatures in Narragansett Bay increased approximately 1.6 degrees Fahrenheit.[96] Even more dramatic is that the average temperature in the Bay during the winter months has increased 4 degrees Fahrenheit from 1960 to the present.[97] Increases in water temperature have been tied to ecological stress, greater storm intensity, and decreased water quality in Narragansett Bay. In addition to temperature increases, we have seen a 71% increase in extreme precipitation events since 1958, events which increase water quality impacts on the Bay from stormwater runoff.[98]

Impacts and Climate Projections

Ecological Impacts - Nutrient Loading

Narragansett Bay is a temperate estuary located along Rhode Island and Massachusetts. As a result, Narragansett Bay maintains a delicate balance of saltwater from the Atlantic Ocean and freshwater inputs from rivers including the Woonasquatucket, Providence, and Seekonk.[99] Nutrients such as nitrogen and phosphorus, found in fertilizers and sewage, are transported from cities and towns into Narragansett Bay through rivers and stormwater infrastructure located throughout the watershed. These nutrients promote microbiological and algal growth in aquatic ecosystems. Significant nutrient discharge have been correlated to hypoxia (low concentrations of available oxygen in the water column) or anoxia (the absence of oxygen) and associated ecological damage.[100] On August 20, 2003, approximately one million fish and shellfish were killed during an anoxic event in Greenwich Bay. During the first three weeks of August 2003, two significant rain events resulted in more than 4.5 inches of precipitation. The resulting stormwater runoff carried raw sewage and other nutrients into Greenwich Bay, which caused a population explosion of phyto-

Dead juvenile menhaden located along the shore in Greenwich Bay (Photo courtesy of RIDEM).

plankton. After the runoff had abated and the associated nutrients were used up, the vast algal blooms were left without nutrients and died off. Decomposing bacteria in the water column consumed the dead phytoplankton, which removed all of the available oxygen from the water column. With no oxygen to breathe, fish and shellfish throughout western Greenwich Bay suffocated and died. Organisms that survived the event still suffered stress that prevented reproduction and other life functions. Residents along Greenwich Bay complained of a rotten egg stench (caused by hydrogen sulfide) at the time of the fish kill. In addition, beaches and coastal access points were littered with the carcasses of marine fauna, which had to be manually collected and buried.[101]

Climate change is projected to result in more extreme storm events, which will in turn result in increased volumes of stormwater runoff.[102] This will cause even greater concentrations of nutrients to enter Narragansett Bay, increasing the risk of more fish kills. Fish kills involving commercially valuable species would cause significant income loss to the fisherman and food service establishments that rely on those species.

Ecological Impacts - Fecal Bacteria Contamination

Enterococcus is the fecal indicator bacteria approved by United States Environmental Protection Agency to determine the potential risk to recreational bathers. These pathogens can cause a wide range of health problems including ear, nose, and throat infections, gastroenteritis, hepatitis, salmonella, and respiratory illnesses. Because there are so many potential pathogens and testing for all of them is not feasible, Enterococci are used as an indicator of the potential presence of these pathogens.[103]

People can become sick from swimming in, or swallowing, polluted water. The most common illness is gastroenteritis, an inflammation of the stomach and the intestines that can cause symptoms such as vomiting, headaches, and fever. Individuals recreating in contaminated water bodies may also experience rashes simply from coming into contact with polluted water (i.e. the skin or eyes). In rare cases, swimmers can develop a serious infection if an open wound is exposed to polluted water (such as vibrio spp.).

Bacteria make their way into Rhode Island's coastal waters through wastewater overflows (primarily combined sewer overflows), stormwater drains/culverts, and run-off from rainfall events. Once in the intertidal zone, bacteria become subject to dilution through wave action flushing. The magnitude of wave action significantly impacts the growth time for bacteria in the shallow waters frequented by bathers. Increased water temperatures due to climate change will cause increased growth for bacteria in these, posing a threat to public health and negatively influencing Rhode Island's economy.[104]

Stormwater and combined sewer overflow is the largest contributor of bacterial contamination to the Narragansett Bay watershed. Traditional methods of storing, transporting, and treating stormwater and wastewater in Rhode Island include: storm drains, combined sewer systems, and wastewater treatment facilities (referred to as grey infrastructure). Over time, long-term maintenance of grey infrastructure suffers as fiscal restraints increase, putting local water bodies at risk. Climate change further exacerbates the shortcomings of grey infrastructure as more intense precipitation events stress these delicate systems.[105] Climate projections demonstrate that increased water temperatures from the Caribbean to New England will result in tropical storms of greater intensity in southern New England. These storms will drastically increase the rate of coastal erosion as well as the amount of rain that falls in a single event.[106] The more rain falling within a shorter amount of time, the greater volume of bacterial contamination will make its way through the watershed and into Narragansett Bay. Enteric fecal pathogens, such as Enterococcus, most commonly cause eye and ear infections and gastrointestinal illness. Pathogens such as Shigella and E. coli can cause severe diarrhea and/or vomiting, dehydration, and abdominal pain/cramping, which may require hospitalization. Beach facilities in Rhode Island have been required to close their waters due to bacterial contamination year after year, causing losses of tens of thousands of dollars of revenue.

Ecological Impacts - Macroalgae

In certain marine ecosystems, warmer coastal water and greater concentrations of available carbon dioxide would also promote greater growth of seaweed (namely macroalgae – chlorophytes, rhodophytes, and phaeophytes).[107] The seaweed does not create enteric pathogenic bacteria; however, it provides protection for existing bacteria against flushing by wave action. As a result, when an input of bacteria occurs at a beach with large quantities of seaweed in the intertidal zone (where nearly all swimmers will be located at the beach) the bacteria will be much more likely to persist within the intertidal zone for a longer period of time. As these mats of vegetation and the associated nutrients become ensnared along the shoreline, the number of beach closure days increases.

Rhode Island beaches have already experienced issues concerning overabundance of seaweed. For several years, massive mats of rhodopyhtes (red seaweed) have been observed during the later summer months in Greenwich Bay, Mackerel Cove in Jamestown, and Easton's Beach in Newport. While this seaweed is not hazardous to humans or domestic animals, it creates a significant nuisance for beachgoers and causes financial loss for the beach facilities.[108] Marine arthropods and insects are drawn to the decaying seaweed and further dissuade potential beachgoers.

Chemical Impacts - Ocean Acidification

Ocean acidification occurs when carbon dioxide in the atmosphere is absorbed by the ocean and forms carbonic acid, resulting in a reduction of pH. Approximately one third of atmospheric carbon dioxide is taken up the oceans.[109] Ocean acidification most notably affects marine organisms with calcium carbonate shells such as oysters, quahogs or other clams, starfish, and coral. Increased concentrations of carbonic acid reduce the amount of available calcium carbonate for these organisms and cause major ecological stress.[110] Under the most severe losses of calcium carbonate, individual organisms may perish. In less severe circumstances, the growth of an organism and/or reproductive capabilities may be inhibited. Decreases in shellfish populations due to ocean acidification may negatively impact local fishermen

and establishments that depend on shellfish for revenue. In addition, shellfish perform important ecological functions, such as removing nutrients and bacteria from the water.[111] Decreased shellfish populations may result in a positive feedback loop, further decreasing marine water quality in Rhode Island.

Cercarial Dermatitis

Cercarial Dermatitis or swimmer's itch is a skin rash caused by an allergic reaction to microscopic parasites that are released from infected salt and freshwater snails. Although the preferred hosts of the parasites are birds and marine mammals, free swimming parasites may burrow under the skin when they come into contact with humans. The parasite will eventually die off but an allergic reaction may cause localized burning, tingling, and itchiness. Cercarial dermatitis is not a serious health risk and may be treated with or without medical attention. The risk of contracting swimmers itch increases with more frequent contact with impacted water bodies, especially those with protected coves that provide ideal habitat for the snails. As climate change in Rhode Island increases our average temperature and the number of extreme heat events, we expect to see people going to the beach more and more often. This will result in an increase in the number of cases of swimmer's itch as more bathers will be exposed to the parasitic larvae.[112]

Freshwater- Fecal Bacteria

Sources of bacterial contamination at freshwater bodies throughout Rhode Island include outdated septic systems, cesspools and holding tanks, wildlife and waterfowl, and stormwater runoff. The lack of dilution due to flushing at freshwater bodies leads to bacterial contamination at irregular frequencies and magnitudes. In addition, due to budgetary constraints, less information is available regarding freshwater than

saltwater. The current monitoring limitations at freshwater beaches puts beach-goers at risk of illness due to potential contamination. Substantial evidence exists to support the importance of monitoring freshwater beaches. Since the Rhode Island Department of Health began monitoring the water quality at freshwater beaches, closure rates have been highly variable. Forty-three of 112 licensed beaches in Rhode Island are freshwater and yet they accounted for 57 percent of beach closure days in 2010. In 2013, freshwater beaches accounted for only 8 closure days out of the 119 total observed during the bathing season. As Rhode Island sees hotter days with increased precipitation, the likelihood of reduced water quality from stormwater runoff and bather load becomes a greater risk for freshwater facilities.[113]

Cyanobacteria

Cyanobacteria (or blue-green algae) are single-celled organisms found in both fresh and saltwater bodies across the world. Currently, species of cyanobacteria that produce toxins (e.g., Microcystin-LR) are prevalent in Rhode Island. When waters are warm and nutrients available, the cyanobacteria undergo an exponential growth known as an algae bloom. During the bloom, levels of toxins can reach levels dangerous for other organisms, including humans and pets.[114] Increased concentrations of nutrients and recent warm weather have led to cyanobacteria advisories for numerous freshwater bodies, as depicted below in Table 3. With further increases in temperature, cyanobacteria blooms will become more frequent with greater magnitude.[115] As a result, efforts to reduce cyanobacterial blooms will have to account for and mitigate the effects of climate change, namely stricter controls on stormwater and the amounts of nutrients that make their way into freshwater bodies.[116]

TABLE 3. RHODE ISLAND WATERS WITH CONFIRMED CYANOBACTERIA BLOOMS IN 2013

Body of Water	Municipality	Date Advisory Posted	Date Advisory Lifted
Mashapaug pond	Providence	7/30/2013	11/2/2013
Roger Williams Park Pond	Providence	7/30/2013	11/2/2013
J.L. Curran Reservoir	Cranston	9/27/2013	11/2/2013
Mellville Ponds	Portsmouth	9/27/2013	11/2/2013

Vulnerable Populations

Children are at highest risk for contracting water-borne illness from swimming in contaminated bathing waters. Fifty-one percent of licensed freshwater facilities in Rhode Island serve children's summer camps. In addition, some waterborne diseases can be transmitted from one person to another after symptoms begin, increasing the chance for an illness outbreak. While all beachgoers are subject to some risk of illness when entering the water, those who are restricted to upper Narragansett Bay have a much greater chance of encountering pathogenic fecal bacteria. Rhode Islanders limited to public transportation have fewer options for beaches than those with their own automobiles and almost all of those options are located in upper Narragansett Bay. The Narragansett Bay Commission (NBC) Combined Sewer Overflow Abatement Project has resulted in significantly better water quality in Narragansett Bay, but municipal-

ities must also take responsibility to ensure that their local water access points are not subject to greater volumes of stormwater runoff as extreme precipitation and storm events increase in the future.

Best Practices in Rhode Island

Several beaches in Rhode Island have employed strategies to improve the quality of their water and reduce the number of closures associated with stormwater runoff pollution. In addition, NBC has overseen the construction of the largest public works project in Rhode Island's history to combat combined sewer/stormwater overflow into Narragansett Bay. These efforts will be essential in the face of climate change as storms of increased magnitude produce greater volumes of stormwater runoff.

Stormwater Runoff Pollution – Narragansett Bay Commission Combined Sewer Overflow Abatement Project

The 64 combined sewer overflows within the NBC's district discharge approximately 2.2 billion gallons of untreated wastewater into Narragansett Bay annually. Beginning in 1993, NBC began planning on a comprehensive combined sewer overflow abatement project to dramatically reduce the volume of untreated sewage entering Narragansett Bay. In 2008, Phase I of the project became operational, which consists of a 26-foot diameter, 3-mile long pipe installed beneath southern Providence. During times of intense rain (the system is designed to handle the volume of runoff associated with a 3-month storm: 1.6 inches of rain within a 6 hour period of time), the massive tunnel acts as a reservoir for combined overflow wastewater. Once the storm has subsided, the wastewater in the tunnel is directed to the Field's Point wastewater treatment plant for treatment before being discharged into Narragansett Bay. Through 2012, approximately 4.6 billion gallons of wastewater that would have otherwise discharged directly into Narragansett Bay were stored and treated as a result of Phase I of the CSO Abatement Project. Phases II and III are expected to become operational in 2014 and 2021, respectively. Once fully operational, the CSO Abatement Project will result in a 98% reduction of untreated sewer/stormwater overflow discharge in Narragansett Bay.[117] The storage capability of this project will be essential in the face of more powerful storms as a result of climate change.

Stormwater Runoff Pollution - Easton's First Beach

Since the implementation of the Beach Program in 2000, Easton's First Beach in Newport had experienced numerous closures each summer. In 2011, Easton's First Beach in Newport installed an ultraviolet disinfection system along the stream that runs from Easton's Pond and discharges into Easton Bay between Easton's First Beach and the Atlantic Beach Club. The system is automatically activated when 0.25 inches of rain or more fall in a 24-hour period of time. Water from Easton's Pond flows through a chamber where the water is subject to intense ultraviolet light. The system was designed to account for elevated concentrations of total suspended solids (TSS), which increase turbidity and limit the penetration of light into the water.[118] Water quality at Easton's First Beach has dramatically improved since the ultraviolet system was installed in 2011, even as precipitation observed during the swimming season has increased.

Ultraviolet disinfection system at Easton's First Beach (City of Newport)

TABLE 4. EASTON'S FIRST BEACH CLOSURE DAYS, 2007 – 2013

	Year	Number of Total Closure Days	Total Precipitation (Memorial Day to Labor Day, in inches)
No UV System	2007	4	8.18
	2008	4	9.64
	2009	3	17.24
	2010	5	13.42
UV System Online	2011	2	14.80
	2012	0	15.00
	2013	0	20.42

Beach Season closures at Easton's First Beach in Newport before and after the implementation of the ultraviolet disinfection system.

Seaweed Removal - Easton's First Beach, Newport

Beginning with the 2009 Beach Season, the City of Newport began using a seaweed harvester to remove seaweed deposited (mostly rhodophytes) along the beach through the tidal cycles. Seaweed removed during low tide is prevented from mobilizing into the water during high tide. However, the seaweed harvester has recently suffered mechanical malfunctions and must be repaired to once again remove seaweed from the beach.[119] With higher temperatures leading to even greater seaweed growth, municipalities will face a difficult battle to maintain clean, accommodating beach facilities.

Stormwater Runoff Pollution - Bristol Town Beach

Since beach monitoring efforts began in 2000, Bristol Town Beach has also experienced water quality impairments. Beginning in 2012, the Town of Bristol elected to restructure the town beach and surrounding area to improve water quality. First, private sewage structures, such as septic systems, in the vicinity of Bristol Town Beach were decommissioned and the properties were connected to the municipal sewer system. Green infrastructure technologies such as porous pavement and rain gardens reduce the amount of stormwater runoff that enters the waters of Bristol Town Beach from the beach parking lot after a precipitation event. A stormwater pipe that received runoff from approximately 95 acres of land located north of the town beach was removed and replaced with an open, meandering stream. The stream slows the movement of stormwater, and specialized vegetation planted along the banks of the stream remove bacteria and nutrients from the water before it reaches the beach. Bioswales installed along the parking lot and stream further capture stormwater runoff and remove potential microbial and chemical pollutants.[120]

Bristol Town Beach after green infrastructure improvements (Town of Bristol)

TABLE 5. BRISTOL TOWN BEACH CLOSURE DAYS, 2007-2013

Year	Number of Total Closure Days	Total Precipitation (Memorial Day to Labor Day, in inches)
2007	6	8.18
2008	4	9.64
2009	12	17.24
2010	5	13.42
2011	4	14.80
2012	6	15.00
2013	0	20.42

Beach Season closures at Bristol Town Beach before and after the implementation of green infrastructure improvements installed in 2012.

SafeWater RI: Ensuring Safe Water for Rhode Island's Future[121]

In January 2012 the Rhode Island Department of Health (HEALTH), Office of Drinking Water Quality, launched SafeWater RI: Ensuring Safe Water for Rhode Island's Future. The project studied the impacts of climate change on drinking water utilities in the state and provided specific information for water utility managers to evaluate and plan for their future.

The objectives of the project were to assess how temperature, rainfall, and other changes might impact Rhode Island, and to develop strategies to address these changing conditions.

The project included the following phases.

Phase 1 – SafeWater RI conducted a survey of drinking water utilities and met with many utility representatives to compile data and information for the project.

Phase 2 – SafeWater RI assessed the impact of changing environmental conditions on drinking water utilities.

Phase 3 - SafeWater RI identified appropriate management strategies that could help make those impacts less severe.

Phase 4 - SafeWater RI identified specific recommendations for utilities, as well as state and local governments, to help them develop and implement outreach activities to reach audiences that will be affected by the management strategies identified in Phase 3.

Now in Phase 4, the Office of Drinking Water Quality is focused on work closely with the utilities to ensure that outreach and education activities are created and put into practice.

Faces of climate change: Walter Burke

Walter Burke, director of Parks and Recreation in Bristol, led the efforts to improve water quality in Bristol's parks. "I'm one of ten kids, I've worked for 25 years taking care of children; children are very important to me," Burke explains. "I've also seen how the natural world has been taken away from our children, under the auspices of protection by moms and dads that don't want their kids to catch poison ivy… We're training our children not to have a love and respect for the outdoors."

Several years ago, Bristol Town Beach closed 15-20 times per year due to water quality issues. Led by Walter Burke, the Bristol Parks are cleaning up their act. They have implemented a diverse range of interventions in the past several years, everything from installing six bio-retention rain gardens to installing a pervious pavement patio. Their efforts have certainly paid off; the beach experienced an 80% improvement in water quality in 2012, and the Bristol Town Beach did not have a single closure in 2013.

Next Steps

Looking to the future, the Climate Change program will continue working with statewide partners to address short and long-term issues of water quality. Working with Watershed Watch at the University of Rhode Island, we have digitized over 20 years of water quality data from our fresh and salt water bodies. With this data we will analyze the results, identify target high risk areas, and develop and pilot appropriate adaptation strategies for varying populations and target audiences.

Three strains most often attributed to cases of illness in Rhode Island are Vibrio (V.) parahaemolyticus, V. cholerae, and V. vulnificus. These strains are specifically linked to food-borne illness and wound infections.

Vibrio parahaemolyticus is predominantly found in Rhode Island coastal waters when temperatures reach 64 degrees Fahrenheit and above.

Reducing the growth of Vibrio bacteria in Rhode Island coastal waters and ponds is no simple task, but protecting ourselves and our families from contracting Vibrio is possible.

Through safe harvesting, transporting, storing, and cooking of shellfish we are able to reduce the risk of illness while preserving a vital economic industry for the state.[v]

VIBRIO

Vibrio is a diverse group of marine bacteria found naturally in coastal waters. Vibrio species are both pathogenic and non-pathogenic and can be found all over the world.[122] In RI, Vibrio has the potential to cause disease when infected shellfish are harvested and eaten. While some Vibrio strains are able to survive in cooler waters, the strains most often in Rhode Island prefer waters warmer than 60 degrees Fahrenheit.[123]

Densities of Vibrio bacteria are expected to increase as coastal water temperatures also increase.[124] As climate change in Rhode Island is projected to bring an increase in ocean temperatures, precipitation, and hotter days, greater risk of food-borne illness and major economic impacts for our shellfish industry are expected. Closing growing and harvesting waters eliminates jobs, puts a higher demand on importing shellfish, and conveys a negative view of our natural systems.

To help reduce the risk of illness and protect this vital industry, the state of Rhode Island is taking a proactive approach by implementing a Vibrio Control Plan, conducting in-depth water temperature data analyses, and promoting educational initiatives to better understand the correlation between climate change and Vibrio illness. Together, Rhode Island's shellfish industry, state and local governments, and concerned citizens are working hard to build Vibrio awareness in a changing climate.

Health Impacts and Vulnerable Populations

There are many strains of Vibrio bacterium, but fortunately few pose a risk to public health. Three strains most often attributed to cases of illness in Rhode Island are Vibrio (V.) parahaemolyticus, V. cholerae, and V. vulnificus. These strains are specifically linked to food-borne illness and wound infections.

The highest risk of Vibrio comes from consuming raw or undercooked seafood. Shellfish are filter feeders and accumulate Vibrio through filtering waters that contain the bacteria. Of all shellfish, oysters are the most likely to cause illness. Oysters filter more water than other bivalves and have thinner gills. This allows more Vibrio bacteria to accumulate causing a higher risk of illness in those eating the oyster raw.[125]

Any person may become ill from Vibrio bacteria, but those individuals with compromised immune systems are most susceptible.

V. parahaemolyticus

Characteristically, V. parahaemolyticus causes diarrhea and other gastrointestinal symptoms including abdominal cramping, nausea, vomiting, and fever. Symptoms typically begin within 24 hours of consumption and last approximately 1-3 days. As with other pathogenic strains, V. parahaemolyticus illness may be more severe in people with compromised immune systems. This strain may also cause infection when warm coastal waters enter an open wound.[126]

Any person may become ill from Vibrio bacteria, but those individuals with compromised immune systems are most susceptible.

V. cholerae

Vibrio cholera is an acute illness caused by eating raw and undercooked shellfish. Symptoms include diarrhea, vomiting, muscle cramps, rapid heart rate, and in more severe cases, low blood pressure. V. cholerae causes the disease known as cholera. It can be mild and is easily treatable. However, in the developing world Cholera can be very severe and potentially deadly.[127]

V. vulnificus

Vibrio vulnificus can cause serious illness in people with underlying medical conditions such as liver disease and compromised immune systems. V. vulnificus infections do not spread from person to person but through an open wound that is exposed to warm coastal waters containing the bacteria. V. vulnificus may also be contracted by eating raw or undercooked shellfish. Among healthy people, ingestion of V. vulnificus can cause vomiting, diarrhea, and abdominal pain. In immunocompromised persons, particularly those with chronic liver disease, V. vulnificus can infect the bloodstream, causing a severe and life-threatening illness characterized by fever and chills, decreased blood pressure (septic shock), and blistering skin lesions. V. vulnificus bloodstream infections are fatal about 50% of the time.[128]

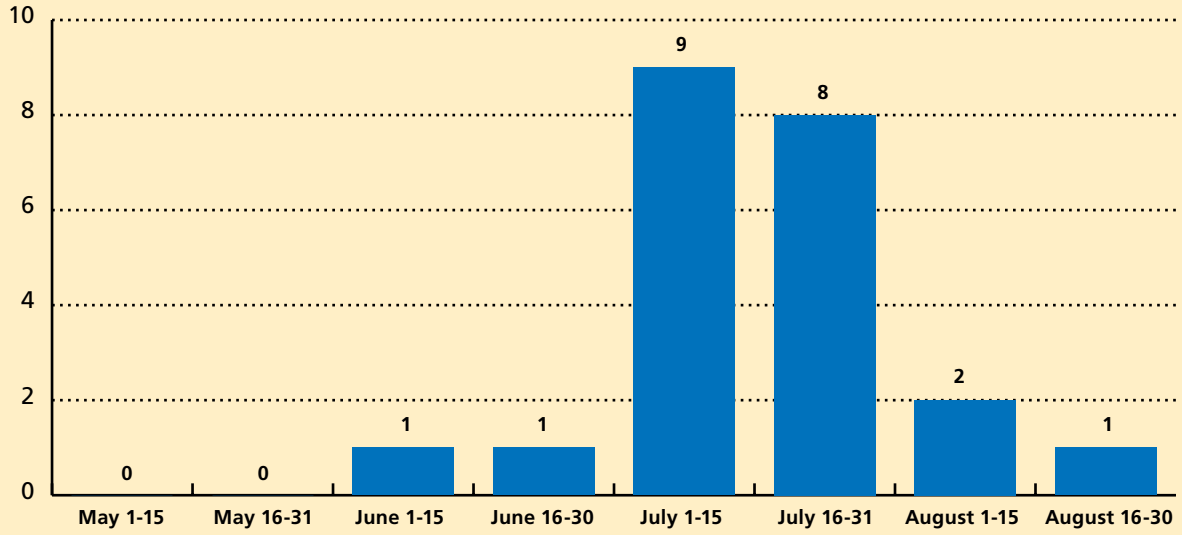
Vibrio in Rhode Island

Vibrio parahaemolyticus is predominantly found in Rhode Island coastal waters when temperatures reach 64 degrees Fahrenheit and above.[129] This threshold is usually met by early to late June with peak water temperatures occurring in late July and early August.[130]

The Rhode Island Department of Health, Division of Infectious Disease and Epidemiology (IDE) investigates, tracks, and reports on Vibrio illness. Epidemiologists work with local officials and neighboring states to identify possible causes of illness and isolate sources of confirmed strains. In addition, while all reported cases of Vibrio illness are documented and investigated, a Vibrio "outbreak" is only reported when two or more members of different households are linked by a common source such as a restaurant or harvest area. Fortunately, Rhode Island has never experienced a Vibrio outbreak.

Utilizing data collected by IDE, the Rhode Island Climate Change Program analyzed all documented illnesses occurring in 2013. This data highlights the extent of Vibrio illness in Rhode Island and the potential rise in cases that may come from increasing water temperatures.

TABLE 6: NUMBER OF REPORTED VIBRIO ILLNESSES BY MONTH, RHODE ISLAND, 2013



*Date based on the onset of symptoms

In 2013, Rhode Island experienced 22 illnesses from exposure to five different strains of Vibrio bacteria. Seventeen individuals experienced gastrointestinal illness, while five individuals suffered various wound infections. Rhode Island residents who experienced illness varied in age from nine to 83 years old. Table 7 illustrates the range in illness.

TABLE 7: VIBRIO STRAINS AND ASSOCIATED ILLNESS, 2013

Strain of Bacteria	Number of Illnesses	Gastrointestinal Illness	Wound Infection
Vibrio parahaemolyticus	15	14 of 15	1 of 15
Vibrio cholorae	1	1 of 1	0 of 1
Vibrio fluvialis	2	2 of 2	0 of 2
Vibrio alinnolyticus	2	0 of 2	2 of 2
Vibrio vulnificus	2	0 of 2	2 of 2

Although it is not always possible to trace Vibrio illness back to its source, some of the most common causes seen in Rhode Island include those listed in Table 8.

TABLE 8: POTENTIAL SOURCES OF VIBRIO ILLNESS IN RHODE ISLAND

	Potential Causes of Illness	Approximate Percentage of Reported Illness
Food Related	Consuming Raw or Undercooked Shellfish	55.0%
	Unsafe Handling	9.0%
	Cross Contamination	5.0%
	Harvest Waters	5.0%
Water Activity	Walking on the Beach	14.0%
	Wading	5.0%
	Swimming	5.0%
Unknown		2%

Illustrated by the data in Table 4, these sources of Vibrio are wide-ranging. From something as simple as walking on the beach and cutting your foot to contaminating cooked food with raw food, Vibrio can lead to serious health effects. However, the most prevalent source of contracting Vibrio is consuming raw or undercooked shellfish such as oysters and clams. According to illness data collected by HEALTH in 2013, eating raw and undercooked shellfish led to approximately 55% of Vibrio illness in the state. It is important to note however, not all of the shellfish served in Rhode Island comes from our state waters. For the vibrio cases in RI, not all of the individuals consumed RI shellfish and, even for those that did, shellfish from other states with previous outbreaks or active recalls may have been consumed as well. Understanding where our shellfish comes from is very important to protecting public health and preventing illness. A majority of the strains we see here in Rhode Island, and along the eastern seaboard, thrive in warm waters. With increased coastal water temperatures comes an increase in the potential for bacterial growth.

Best Practices

Shellfish filter water as a source of food leaving bacteria, viruses, or pollution in that water to be transferred to the organism. Reducing the growth of Vibrio bacteria in Rhode Island coastal waters and ponds is no simple task, but protecting ourselves and our families from contracting Vibrio is possible. Through safe harvesting, transporting, storing, and cooking of shellfish we are able to reduce the risk of illness while preserving a vital economic industry for the state. Our current and future efforts regarding education and policies will help to ensure that these best practices are being followed.

Monitoring of Harvest Areas

When harvesting shellfish it is important to dig in approved waters. Like many states, Rhode Island has set a standard for waters approved for shellfish harvesting. These waters are monitored for bacteria, viruses, and toxic algae that could contaminate shellfish and their growing waters. The Rhode Island Department of Environmental Management identifies both safe waters and those that are closed due to unsafe conditions.[131]

Transporting

Shellfish may become vulnerable to bacterial growth during transport from harvest waters to their destination. Keeping shellfish on ice (not in water) and out of the sun will help ensure safe temperatures are sustained during this time. Ideally, temperatures should remain at 45 degrees Fahrenheit or below. Additionally, the use of coolers and ice are encouraged to help maintain temperatures.[132]

Storing

When stored properly, harvested shellfish can last for several days. In accordance with the National Shellfish Sanitation Program Model Ordinance, the safe storage of shellfish is 45 degrees Fahrenheit or below.[133] To further reduce the risk of illness raw shellfish should be stored below cooked food to prevent contaminating cooked food items with dripping water.[134]

Cooking

While shellfish is considered a ready-to-eat food, HEALTH recommends cooking shellfish to a temperature of at least 145 degrees Fahrenheit for 15 seconds.[135] Fully cooking shellfish is one of the best ways to prevent Vibrio illness. The cooking process kills harmful bacteria and other potential pathogens that may be present. Once shellfish is fully cooked it is important to keep it away from other raw foods and utensils used with raw foods that may cause cross contamination.[136]

Current Projects

Water Quality Analysis: University of Rhode Island Watershed Watch

The Rhode Island Climate Change Program is currently working to better understand the link between Vibrio illness and ecological indicators to help identify high-risk water bodies and predict illness. Having acquired 20 years of historical data at 37 marine sampling sites, the Climate Change Program is examining the water temperature, salinity, and depth of all shellfishing water bodies in Rhode Island for trends that may help shed light on this growing problem. Phase I of this analysis will concentrate on areas of the upper Narragansett Bay and six coastal ponds.

Vibrio Parahaemolyticus Control Plan

Beginning July 1, 2014 the Rhode Island Department of Health adopted a Vibrio parahaemolyticus Control Plan for licensed oyster growers. The current plan oversees oyster aquaculture during the summer months, however by 2015 the plan will be expanded to include regulations for shellfish dealers as well. Wild harvesting of oysters during the summer is illegal in Rhode Island, but allowed in both Massachusetts and Connecticut. This provision may be one factor keeping our illness rates to half of what our neighboring states have faced. In July 2014, the Rhode Island Department of Environmental Management

(DEM) adopted their own Vibrio plan for growers, which regulates the licensing and conditions under which aquaculture should be conducted.

The purpose of our Vibrio Parahaemolyticus Control Plan is to reduce the likelihood of illness during times of the year that have historically been associated with illness. The new rules require that from July 1 through Sept. 14 all non-wild and commercially harvested oysters from enclosed water bodies, such as coastal ponds, must be delivered to a dealer and refrigerated or placed in ice within two hours of the first harvest — the limit is five hours for oysters from the open bay — to cool the animal's internal temperature to 50 degrees; which is the temperature when Vibrio growth and reproduction is greatly diminished. All oysters must also be put in a shaded location immediately upon harvest, and those oysters that have been removed from the water for husbandry purposes must be re-submerged for two to seven days before being harvested.

Proper cooling of oysters to prevent bacteria growth

The United States Food and Drug Administration requires the adoption of Vibrio Control Plans when a state has experienced two or more illnesses traced back to one water body. Rhode Island has not experienced more than one case traced back to state waters, but given our neighboring states' experiences we have proactively and voluntarily adopted a plan. This decision is the most protective of public health and contains many requirements such as annual risk assessments, ecological data collection, updated temperature requirements for cooling, permitting requirements and gear requirements to name a few.

Climate change poses a serious threat to aquaculture and the methods and regulations discussed above. As water temperatures continue to rise, the safe practices mandated by HEALTH and DEM may no longer be sufficient. Water temperatures in Narragansett Bay have risen on average by almost 2 degrees Fahrenheit and, even more dramatically, in the winter months by 4 degrees. As these trends continue, the risk of Vibrio may increase as well, especially outside of the regulated timeframe (July 1-September 14). It will be imperative for HEALTH and other partners to continue monitoring water temperature to ensure that the timeframe for regulations is appropriate.

Next Steps

HEALTH, DEM and our partners in the shellfish industry will collaborate over the next year to develop a Vibrio Control Plan for all shellfish. This plan will go into effect July 1, 2015.

At the same time, the Climate Change Program will continue working with the Office of Food Protection and DEM to develop strategies to plan for climate risks, training, and education. For 2015, we will develop a pilot program which will include educational materials and signage specifically targeted towards recreational diggers. The pilot program will be focused on safe handling and appropriate site selection for digging. We will also provide data and materials to our partners in the Office of Food Protection so that they may incorporate climate data, projections, and potential risks for the future into their long-term planning.

The Centers for Disease Control and Prevention define vector-borne diseases as bacterial and viral diseases spread by mosquitoes, ticks, and fleas.[vi]

Climate change has the potential to significantly increase the risk of tick- and mosquito-borne disease in Rhode Island, especially for certain vulnerable populations. Of course, climate change is only one of a number of factors driving vector-borne disease growth in the U.S. Other factors that may be facilitating the spread of vector-borne disease include viral evolution, land use change, and trade.

VECTOR-BORNE DISEASE

As climate change forces public health practitioners to reevaluate global disease risks, vector-borne diseases, especially those transmitted by mosquitoes and ticks are of particular concern. Because vector population dynamics vary significantly with environmental change, vector-borne diseases are particularly sensitive to climate change. Although it is difficult to predict future trends in vector-borne disease, many researchers agree that the effects of climate change are likely to increase the global burden of vector-borne disease.[137] Climate change will act upon vector-borne disease in multiple ways, affecting the transmission and survival of vectors and altering patterns of infection with changes in population dynamics.

Tick-borne Lyme disease impacts more people in Rhode Island compared to other vector-borne diseases, including tick-borne babesiosis and anaplasmosis, as well as mosquito-borne West Nile and Eastern equine encephalitis virus (EEEV).

The Centers for Disease Control and Prevention define vector-borne diseases as bacterial and viral diseases spread by mosquitoes, ticks, and fleas.

Trends and Climate Projections

With climate change, temperature is rising, and humidity, precipitation, and cloud cover are changing. An extensive body of research indicates that these climatic factors have a significant impact upon the biology and ecology of many of the vector-borne diseases that affect human health worldwide.[138]

In the United States, some vector-borne diseases have been present for hundreds of years, while others have arrived more recently, their range expanded by globalization, trade, and environmental changes. As the influence of these factors continues to grow, the burden of vector-borne disease in the U.S. is expected to increase. A growing body of research is attempting to project trends in vector-borne disease using climate modeling. Results are difficult to generalize; even within the U.S., projected trends vary dramatically based on local conditions. Nevertheless, the World Health Organization recommends strong surveillance throughout the country to manage a projected overall increase in risk arising from changes in disease patterns.[139]

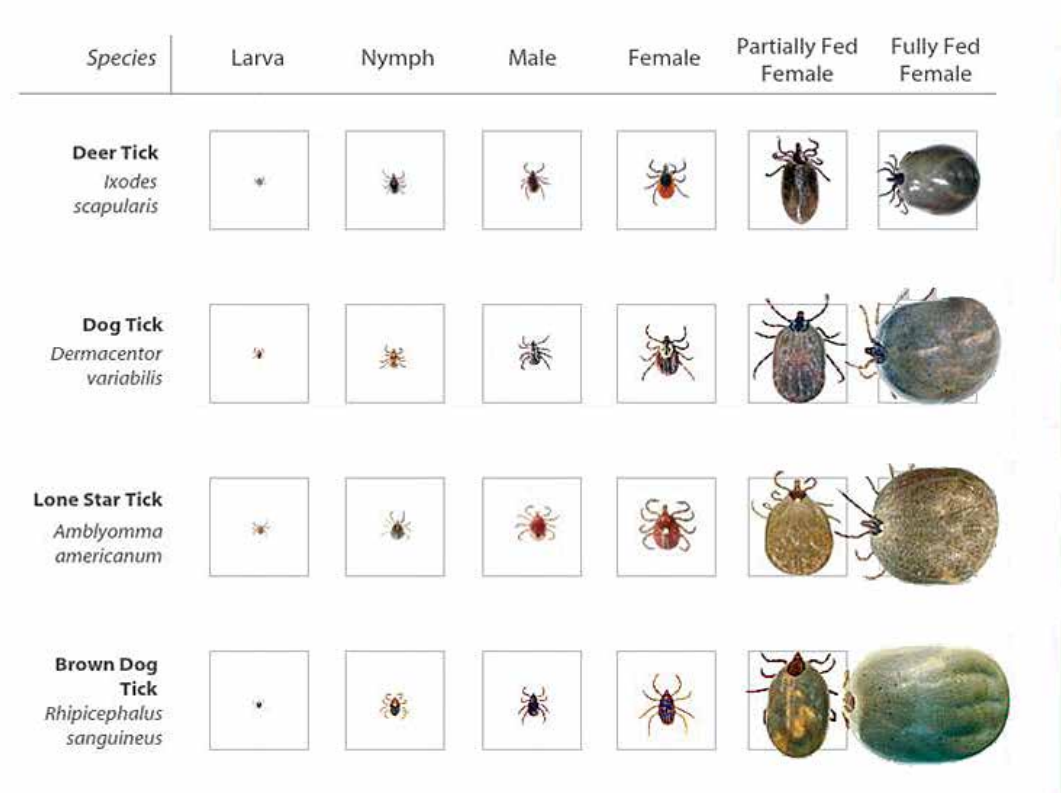
Although the risk of vector-borne disease infection may rise with climate change, the burden of vector-borne disease in the U.S. is expected to remain much lower than the burden in developing countries, because the health infrastructure in developed countries will be better able to respond to emerging threats.

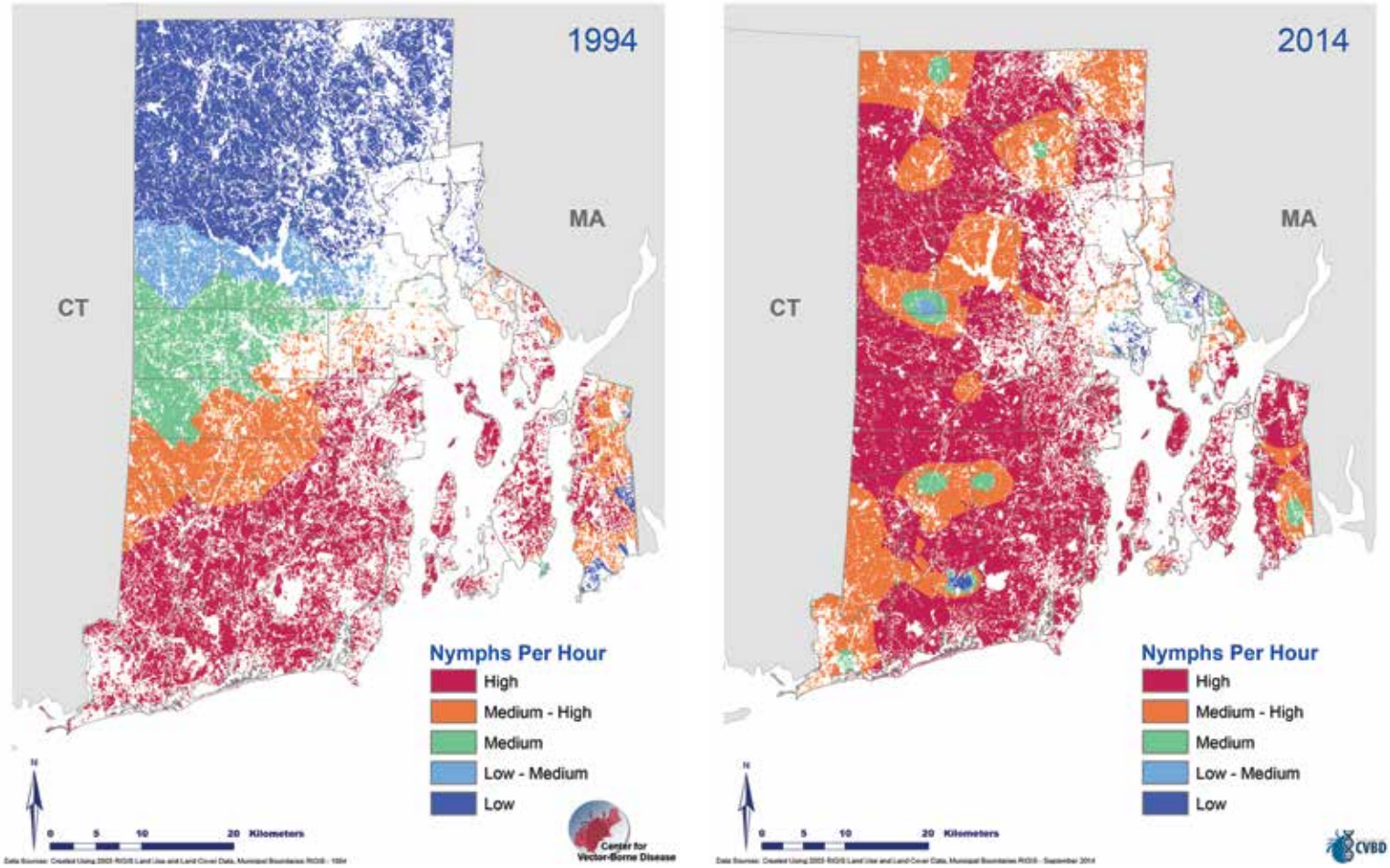
Ticks

Tick-borne disease poses a unique challenge in the United States. Lyme disease is the most prevalent vector-borne disease in the U.S.[140] and is endemic in much of Rhode Island.[141] The Lyme pathogen, Borrelia burgdorferi, is spread through the bite of an infected tick. The primary tick carrying Lyme disease in North America is the black-legged tick, Ixodes scapularis, commonly known as the deer tick.[142] Although less prevalent than Lyme disease in Rhode Island, babesiosis has been observed, and overall human babesiosis incidence is increasing in the state.[143] The infectious agent, Babesia microti, is also spread through the bite of an infected deer tick. Reported cases of babesiosis in humans are concentrated in the Northeast and upper Midwestern U.S., especially in the coastal islands of Rhode Island, Connecticut, New York, and Massachusetts.[144] Indeed, babesiosis is endemic in RI's Block Island.[145] Patterns of both Lyme disease and babesiosis are following the expanding range of deer ticks.[146,147]

Several other tick-borne diseases are present in Rhode Island. Anaplasmosis (also known as human granulocytic anaplasmosis and granulocytic ehrlichiosis) is prevalent in ticks in New England. Anaplasmosis, while uncommon, occurs at a higher rate in Rhode Island than any other state in the U.S. (36.5 cases/million).[148] Rocky Mountain spotted fever and tularemia are rare in Rhode Island, but cases have been reported.

TICK ENCOUNTER RESOURCE CENTER TICK IDENTIFICATION CHART





Tick density in Rhode Island – 1994 and 2014
Images from the Tick Encounter Resource Center

The number of ticks in Rhode Island is rising over time, and this trend may be partially attributable to climate change. University of Rhode Island tick expert Thomas Mather notes that 2013 was the second consecutive record-breaking year for tick numbers.[149] This population growth and spreading across RI may have profound implications upon tick-borne disease in the state. In several Rhode Island communities, the density of infected ticks was strongly correlated with incidence of Lyme disease.[150] Because tick density increases the probability of pathogen exposure, it is likely that increases in tick density will increase overall tick-borne disease transmission rates.[151]

Climate Projections

The deer tick, the primary vector of Lyme and Babesiosis in the area, is very sensitive to climatic varia-tion.[152,153,154] A deer tick is susceptible to desiccation, and its body can dry up with changes in the surrounding environment. Because ticks are sensitive to moisture levels, changes in ambient humidity can dramatically affect the vector populations.[155] The TetraTech models indicate that changes in relative humidity during Rhode Island summers will be small; without increased dryness, the higher temperatures will allow tick populations to flourish.[156] Temperature also affects tick population dynamics. There is an inverse relationship between tick survival and the amount of subfreezing temperature exposure, and fewer cold winters could increase tick survival.[157]

Furthermore, climate change may alter tick habitats, changing habitat suitability for the vectors. Warming and other climate trends may cause vector population redistribution or expansion. Research suggests that tick range in North America is expanding north and into higher altitudes due to rising average temperatures.[158] Climate change may also influence the habitat of tick hosts, changing host community composition, and affecting tick population dynamics. For example, the range of Southern reproductive hosts, such as lizards, may expand north with warmer temperatures.[159] Because lizards are inefficient reservoirs for ticks compared to our typical Northern hosts, such as deer and mice, this particular change may result in a reduction of public health effects due to tick-borne disease. However, temperatures in Rhode Island would need to increase dramatically to see lizards as primary hosts versus mice or deer.

Behavioral changes that alter the way humans interact with nature could also affect tick populations and tick-borne disease transmission. If warmer temperatures encourage Rhode Islanders to stay inside during the summer, for example, the reduction in tick exposure could result in lower incidence of tick-borne disease.

Despite an observed increase in tick density in Rhode Island over the past several years, the complex ecological system that supports and sustains tick populations could react to climate change in many different ways. There is not yet a substantive body of research that definitively projects the effects of climate change on tick populations. However, the trends over the past 20 years and our climate projections provide useful information to help us project future growth of the tick population, which may correspond to an increase in Lyme disease risk.[160]

Faces of climate change: Dr. Cathy Lund

Dr. Cathy Lund is the owner of Providence's City Kitty, a cats-only veterinary clinic, and the president of the Companion Animal Parasite Council. Dr. Lund does not see many ticks on cats. Most of City Kitty's clientele are indoor cats with minimum tick exposure. Additionally, cats' rough tongues and fastidious grooming habits keep cats mostly tick-free. Nevertheless, Dr. Lund does believe that every year brings with it a heightened risk of tick exposure for all pets. "It is without a doubt worse than it was twenty years ago in the state," she tells me.
Even though tick-borne diseases like Lyme are not directly transmitted from pet to owner, Lyme disease in companion animals can have an impact on human health. Research indicates that when the incidence of Lyme disease in dogs passes a certain threshold, the human health risk increases dramatically. "Dogs will act as a sentinel for disease in humans," Dr. Lund says. "That's enormously important for us because we do many many more Lyme tests in dogs in general than we do in humans."

Mosquitoes

The most prevalent mosquito-borne diseases in Rhode Island are West Nile Virus and Eastern Equine Encephalitis. Two cases of West Nile virus were confirmed in humans in Providence in 2011, and a Rhode Island Department of Health Division of Infectious Disease and Epidemiology study found two mosquito sampling pools out of 1690 pools that tested positive for West Nile virus in the same year. In the same study, two sampling pools tested positive for Eastern equine encephalitis.[161]

While highlands J virus has been previously detected in mosquitoes in Rhode Island[162] and Malaria has been diagnosed in humans in the state,[163] these diseases are of lower concern than West Nile virus and Eastern equine encephalitis. Dengue fever is not expected to prove a problem in Rhode Island, as outbreaks rarely occur in the continental U.S.[164]

The population dynamics and behavior of mosquitoes are highly susceptible to environmental changes. Climate change is expected influence mosquito vectors and the viruses both directly and indirectly; the combination of direct and indirect effects on disease occurrence transmission could have profound implications upon mosquito-borne disease prevalence and incidence in the area.

Climate Projections

Research has indicated that changes in temperature directly affect mosquito development, mortality, and behavior. Changes in precipitation and evaporation may also alter the primary habitat and range of mosquitoes. Climatic factors such as temperature and precipitation have proven most significant, but other factors like humidity and wind can also be important.[165] The same climatic factors affect the survival and transmission of viruses transmitted from mosquitoes to humans. In particular, ambient temperatures affect pathogen replication rates within the insect.[166]

Research indicates that the two most prevalent mosquito-borne diseases in Rhode Island, West Nile virus and Eastern equine encephalitis virus (EEE), will become more common with climate change. West Nile virus is expected to become more prevalent as the abundance and seasonality of populations of Culex pipens, the primary mosquito vector, are affected by climatic change.[167] Similarly, recent research has identified a link between the increase in EEE incidence in the past ten years and climate change.[168] Risk of less common mosquito-borne diseases may also increase. As vector ranges expand with climate change, mosquito-borne diseases that have not been prevalent in the area previously may present a greater threat. For example, the range of the Asian tiger mosquito (Aedes albopictus) is expanding, enabled by warming global temperatures, increasing the risk of dengue in the continental U.S.[169]

Climate change also affects land use and land cover with altered weather patterns, which can enhance or restrict growth and expansion of vector populations. Human activity may also affect vector population dynamics. Furthermore, habitat changes in response to climate effects may increase or decrease exposure.

Vulnerable Populations

The risk of exposure to vector-borne disease depends on proximity to high-risk environments and the presence of barriers to exposure.[170] People with prolonged exposure to vector habitat are a major at-risk population; both outdoor labor and recreation increase the likelihood of disease transmission. In Rhode Island, people who work or play outside in vector habitats are be particularly vulnerable to vector-borne diseases, especially young children, older adults, and individuals with compromised immune systems. Although the more rural and southern areas of Rhode Island, including Prudence and Block Islands have primarily been the most vulnerable, the risk of tick and mosquito encounters is now spreading across the state.

Current Projects

Lyme Disease Strategic Plan for Addressing Tick-Borne Illnesses in Rhode Island

In partnership with the Climate Change Program, the Division of Infectious Disease and Epidemiology, and HEALTH's Communication office, we developed a draft Lyme Disease Strategic Plan for addressing Tick-borne illnesses in RI. This plan will help guide our efforts and outlines strategies to reduce the burden of tick-borne illnesses in Rhode Island, including:

- Lyme disease
- Babesiosis
- Erlichiosis

The plan has applicability for the entire state with emphasis on:

- High-risk geographic areas
  - Washington County (especially high risk: New Shoreham)
  - Newport County (especially high risk: Jamestown; Prudence Island)
- High-risk occupations
  - Agriculture and landscaping
  - Ecotourism
- High-risk activities
  - Hiking, camping and hunting
  - Some outdoor sports (e.g., golf)
  - Some outdoor athletics (e.g., cross-country)
  - Children's outdoor play (e.g., playing in brushy areas)
  - Outdoor pets (e.g., dogs and cats)

Over time, the plan will continue to address this question: How should the Rhode Island Department of Health, in collaboration with its community partners, work to reduce the burden of Lyme disease in Rhode Island by means of surveillance, prevention, early detection, and medical treatment?

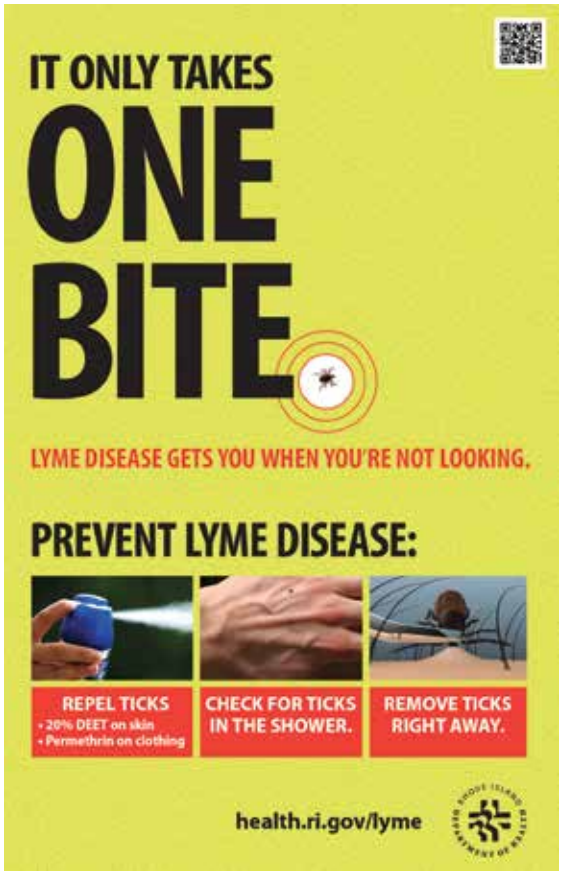
Tick Community of Practice

In partnership with the Maine and New Hampshire CDC Climate Change programs, we have developed a Community of Practice (CoP) to explore and define the issue of Vector-Borne (VB) disease and Lyme disease in relation to climate and health issues. This group will grow to include subject matter experts and potentially other regional partners.

Lyme Disease Prevention Workshops

Working collaboratively with the University of Rhode Island Tick Encounter Resource Center, our program has begun offering tick safety trainings for vulnerable populations. In a unique multi agency partnership, our first two programs were offered in coordination with the RI Department of Transportation and the RI Department of Environmental Management. During our pilot program, we trained over 100 employees who work outdoors. These trainings will continue at DEM and DOT year after year, using a 'train the trainer' model. As a part of the program, tick safety education posters have been distributed to DOT offices and garages, as well DEM offices, park facilities and trailheads. Additionally, tick ID magnets and Permethrin samples have been given to the employees.

Given the overlapping audience, HEALTH's Comprehensive Cancer partnership participated in these trainings and provided support and education for sun safety and skin cancer awareness.



Statewide Lyme Disease Campaign

As a part of the Climate Change Program and the Division of Infectious Disease and Epidemiology, HEALTH led a new initiative to promote personal protection against tick bites and increase public awareness about Lyme disease. Our Communications office launched a tick safety campaign in April 2014; the five-month campaign featured radio advertisements in English and Spanish, newspaper advertisements, bus and ferry banners, and signs in other key areas.

> "We were happy to partner with HEALTH and DEM to bring vital Lyme disease education and training to our work-force as well as to the public," said RIDOT Director Michael P. Lewis. "Their health and safety is our highest priority, and we are committed to providing the resources people need to protect themselves while working and recreating outdoors."

Lyme Disease Prevention Toolkit

Lyme disease and tick bite prevention outreach activities include our Lyme Disease Prevention Toolkit for RI Schools and Camps. The toolkit includes educational print materials, as well as an activity kit for elementary school aged children. The activity kit was developed by the URI TickEncounter Resource Center and includes fun lessons, games, and resources. The Climate change program has the activity kits available for schools, camps, and athletic teams to borrow. The toolkit was distributed electronically to all public and private schools and to school-nurse teachers in Rhode Island in preparation for Back-to-School planning for the fall, as well as to all area summer camps and athletic leagues that serve RI youth. In response to this outreach, several schools and camps have utilized the activity kits. The kits and print materials have been distributed at various events, such as DEM's Great Outdoors Pursuit and at back-to-school fairs for parents.

"The Department of Environmental Management is dedicated to providing families with fulfilling outdoor experiences," said DEM Director Janet Coit. "At the same time we promote experiencing the great outdoors and help families learn how to latch onto nature, we have to help them learn now to keep nature from latching onto them, via ticks. We've learned that we need to take several approaches to deal with this concern, including partnerships, public education, and deer population control. Our joint effort with the Departments of Health and Transportation to offer training sessions and tick prevention education information to the public will help spread the word about the many dangers involving ticks and how to prevent tick bites."

Mosquito Safety Toolkit

A mosquito-borne disease educational toolkit was developed for schools, camps, and athletic groups. The toolkit includes printable materials for parents, teachers, school nurses, and others who are interested in learning more about mosquito-borne diseases and prevention.

Tick-borne Disease Surveillance

From 1998 to 2003, the state had federal money to help track Lyme. Unfortunately, in 2004 the funding was cut and HEALTH switched to "passive surveillance," reporting cases that were disclosed to the department, but not making additional inquiries. The impact this had on reported Lyme cases was drastic. RI had 736 cases reported in 2003, but by 2004 only 249. Since these changes, our state epidemiologist has had a strong belief that we have around 800 cases of Lyme per year, although this is difficult to estimate without a program in place.

Although we have limited reporting in the state, passive surveillance still gathers the needed information about where, when and among whom Lyme disease is most prevalent. These trends that can help to identify those most vulnerable and inform our education and outreach programs. From the 2008-2012 data there are some highlights. Children, ages 5-9, and older adults, ages 50-79, are the highest risk groups and Washington County has the highest reported rate of disease.

FIGURE 9. RATE OF LYME DISEASE BY AGE GROUP, RHODE ISLAND, 2013

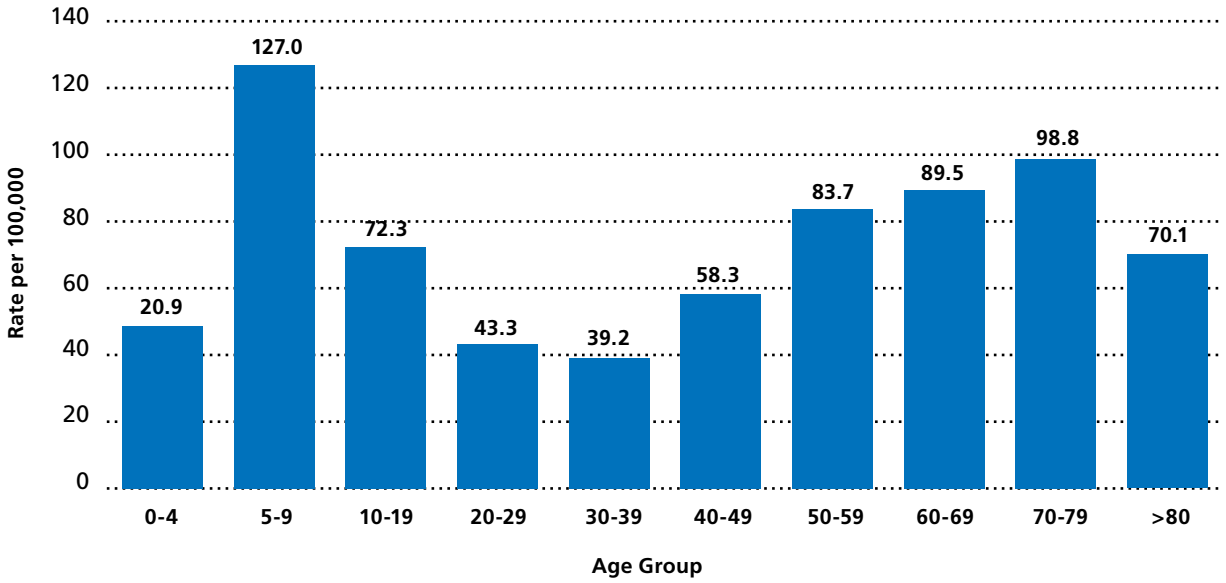
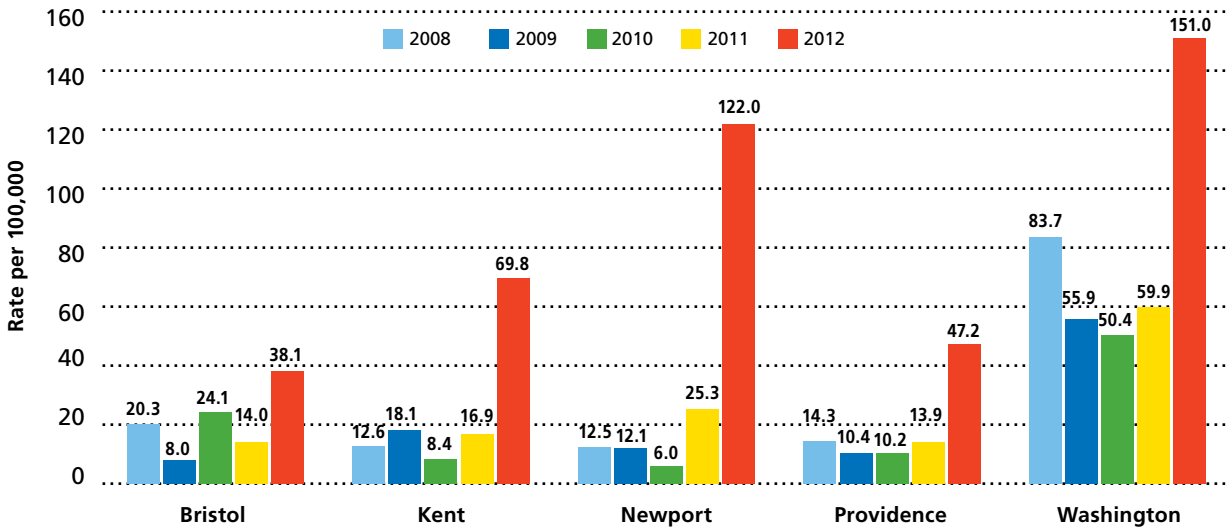


FIGURE 10. RATE OF LYME DISEASE BY COUNTY AND YEAR, RHODE ISLAND, 2008-2012



The months of April thru September are the highest risk periods and the times when education and outreach should be prioritized. Although there are no plans in place to develop a formal Lyme surveillance program, we hope that in the future we can expand the work being done to track cases in Rhode Island. Using our existing data and with support from research being conducted at URI, we will continue to expand our outreach, education, and Lyme prevention activities.

Mosquito-borne Disease Surveillance

The Rhode Island Department of Health Mosquito Task Force has implemented an arbovirus surveillance program to track changes in vector population dynamics across the state. As a part of the Task Force, the

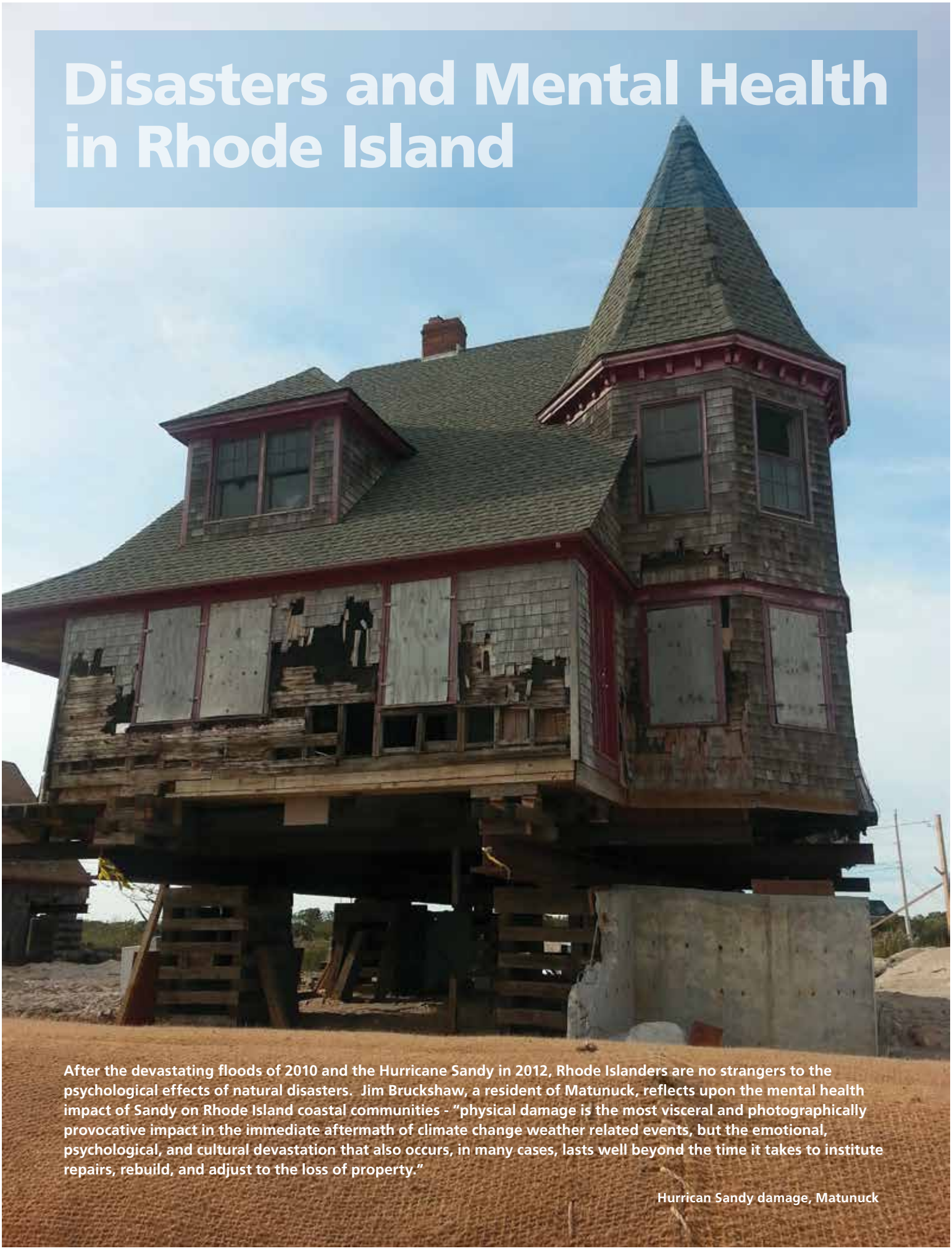
Department of Environmental Management and the University of Rhode Island trap mosquitoes at sites throughout the state and test samples for the presence of West Nile Virus and Eastern equine encephalitis. Based on the sampling findings, the State will issue alerts and advisories to the public regarding both West Nile and EEE. Unfortunately, these alerts and advisories present numerous challenges for public health messaging. The advice to stay inside during the most vulnerable time, dusk, runs counter to other HEALTH messaging offered to the public. In the past, high school sporting events have been canceled as a result of a mosquito advisory and people have stayed inside, rather than exercising. During the warmer seasons, when mosquitoes are present, heat and air quality is also a problem in Rhode Island. HEALTH often recommends that people exercise and spend time outdoors later in the day, once it has cooled down and air quality has improved. These contradictory messages make it difficult to give our residents clear and consistent information. HEALTH is continuing to develop messages that give RI residents the information they need to make sensible and healthy decisions.

Next Steps

Climate change has the potential to significantly increase the risk of tick- and mosquito-borne disease in Rhode Island, especially for certain vulnerable populations. Of course, climate change is only one of a number of factors driving vector-borne disease growth in the U.S. Other factors that may be facilitating the spread of vector-borne disease include viral evolution, land use change, and trade. In a warming world, the future of dengue in Rhode Island remains uncertain, but the necessity to prepare for enhanced disease risk because of these factors is indisputable.

HEALTH will continue to grow our education programs and reach additional target audiences. Working with our partners throughout New England, we will build on our Community of Practice to address tick-borne diseases and the best practices for motivating behavior change with our residents to reduce disease rates. While we do not have plans for improved disease surveillance, we hope that in the future opportunities will arise so that we can improve our program and have a clearer understanding of the disease burden in Rhode Island.

Disasters and Mental Health in Rhode Island



After the devastating floods of 2010 and the Hurricane Sandy in 2012, Rhode Islanders are no strangers to the psychological effects of natural disasters. Jim Bruckshaw, a resident of Matunuck, reflects upon the mental health impact of Sandy on Rhode Island coastal communities - "physical damage is the most visceral and photographically provocative impact in the immediate aftermath of climate change weather related events, but the emotional, psychological, and cultural devastation that also occurs, in many cases, lasts well beyond the time it takes to institute repairs, rebuild, and adjust to the loss of property."

Hurrican Sandy damage, Matunuck

MENTAL HEALTH

Climate can influence an individual's mental well-being in many different ways and is already affecting the social and environmental determinants of mental illness.[171,172] While direct impacts of climate change (such as increased intensity and frequency of extreme weather events) may have more immediate effects on mental health, global warming's indirect impacts will contribute to longer-term effects on mental health as the climatic changes act upon the determinants of mental illness. Climate change can also act indirectly by affecting physical health or community well-being.[173] Additionally, the conceptual threat of climate effects can create emotional distress and anxiety about the future.[174] Although there is not an extensive body of research analyzing the psychological responses of individuals and communities to climate change effects, some researchers believe that the severity of mental health effects depends on whether there is sufficient individual or group coping and community or institutional support.[175]

According to a study completed in 2011, Rhode Island had the highest serious mental illness rate in the nation with 7.2% of residents having a serious mental illness, compared with a national rate of 4.6 percent.[176] Nearly one in five Rhode Island residents has experienced a form mental illness in the past year.[177]

In the past, research into the public health implications of climate change has focused primarily on the physical elements of health. The emerging burden of climate effects on mental health has not been thoroughly investigated. Understanding the psychological and social implications of climate effects is vital to promoting community resilience to climate change. Here, we address climate change's possible effects upon mental health and discuss implications in Rhode Island.

Climate Projections and Health Impacts

The effects of climate change on mental health will vary dramatically based on the nature of the climate event and the unique circumstances of the individual, group, or area affected. For the purpose of this report, we have organized the mental health implications by climate effect, and divided the climate effects into 'rapid onset' and 'slow onset' categories based on the character of the event.

Rapid-onset events

Rapid-onset climate events, such as heat events and flooding, may become more frequent and variable with climate change. Acute climate impacts may impact the mental health of populations on both a personal scale (such as depression following an injury) and a societal level (like anxiety resulting from displacement after infrastructure damage).[178] The psychosocial effects of specific types of impacts vary depending on the nature and context of the event. In general, however, the link between acute climate events and extreme anxiety reactions, such as acute stress disorder (AS) or post-traumatic stress disorder (PTSD), is well established. Because climate change is expected to cause an increase in the frequency and intensity of extreme weather events, people will increasingly be exposed to the causes of PTSD, such as trauma.[179]

Cranston, March 2010

Heat events

In Rhode Island, the average number of days with "danger" heat advisories, when the risk of heat-related illness is highest, is projected to increase from 1 to 4 per year by 2084.[180] There is very little evidence that the development of specific mental health concerns is associated with extreme heat events; much of the research focuses on extreme heat's effect on existing mental health problems. However, several studies do suggest that extreme heat events may be accompanied with a general increase in aggression.[181]

Mental, behavioral, and cognitive disorders may be triggered or exacerbated by higher temperatures. Individuals that are already affected by mental illness are particularly vulnerable to health effects; pre-existing mental conditions triple the risk of death during a heat wave.[182] In a study of the effect of heat waves on mental health in a temperate Australian city, researchers found that several mental health disorders are especially sensitive to exposure to high ambient temperatures. The study showed an overall increase in hospital admissions for mental and behavioral disorders above approximately 80oF, and a 7% increase in admission during heat waves. Affective disorders were particularly affected by heat events,

with hospital admissions for mood disorders increasing 9% during heat waves. Additionally, deaths due to psychoactive substance abuse increased significantly in females during the heat wave.[183]

Extreme Weather

As a coastal state, Rhode Island is particularly vulnerable to the increased flooding and storm tides that may result from climate change. The March 2010 floods in the Northeastern US were especially devastating to Rhode Island; residents remember the event as the "Great Flood of 2010." Although the flooding caused about $330 million in property damages across Rhode Island, New Jersey, Massachusetts, and Connecticut, no research has estimated the extent and costs of the physical and mental health impacts of this event. With climate change, the frequency of similar high-intensity flooding events, both riverine and coastal, may increase.[184] Additionally, the increased intensity and frequency of extreme storms may contribute to more numerous and intense storm surges.[185]

An extensive body of evidence implicates extreme weather events in the development of mental health disorders associated with loss, social disruption, and displacement.[186,187,188] The effects of extreme weather events on a population can be cumulative; repeated extreme weather events can increase the burden of these mental health disorders upon those affected by disasters.[189] The mental health effects vary greatly depending on the severity and suddenness of the event and the social, historical, and cultural context of the location and population.[190]

The population affected by Hurricane Katrina exhibits high rates of PTSD. This population also experiences high rates of depression, domestic violence, and suicide attempts and completions (Larrance 2007). Researchers believe that these mental health effects are attributable partially to the actual event, and partially to the economic and social aspects of the aftermath.

In the short term, acute traumatic stress is the most common response to disasters. Symptoms often diminish once conditions of safety have been re-established.[191] Some affected individuals may continue to experience chronic disorders, such as PTSD, complicated grief, anxiety disorders, somatic symptom disorders and substance abuse.[192] Although the development of mental disorders is most often studied in adults, there is evidence that children may also develop PTSD and behavioral issues after a natural disaster.[193]

Research on mental health effects of flooding is particularly well-represented in the literature. Research suggests that, in general, mental health problems increase after a flood.[194] Long-term anxiety and depression, PTSD, increased aggression in children, and increased rates of suicide have been associated with flooding events.[195]

Extreme weather events and floods catalyze long-term, population-level changes that can have profound effects upon mental health. Natural disasters can act indirectly upon mental health by destroying landscapes, affecting physical health, and disrupting community well-being.[196] One oft-overlooked effect on mental health is the financial hardship due to loss of employment in climate-sensitive industries, such as fisheries or tourism.[197] Job loss may result in increased depression, anxiety, and decreased self-esteem

Hurrican Sandy damage, Matunuck

and life satisfaction.[198] Additionally, the reduction in income that follows an acute weather event can be exacerbated by the increased cost of goods and services following a disaster.

Displacement after an extreme weather event may also have impacts upon the mental health of a population. Displaced individuals may experience depression and trauma associated with the loss of home, place, and social networks.[199] Trying to reestablish residence, find work, and recover from the trauma of the event can result in stress.[200] Moreover, displacement fractures existing social and community networks, disrupting informal mental health support systems offered by the community.[201]

Slow-onset events

There is very little evidence about mental health and sub-acute climate impacts, but these 'chronic disasters' may have similar mental health effects to acute disasters.[202] Individuals and communities affected by slow-onset effects, such as gradual temperature change or sea level rise, experience multiple adversities that accumulate over time in their lived experiences. Mental health problems that commonly develop following multiple adversities can be expected, such as chronic psychological distress and generalized anxiety.[203] These slow-onset climate effects, such as sea level rise, temperature, and drought, will likely have a variety of mental health implications for Rhode Island residents.

Sea Level Rise

Rhode Island is facing a potential 3 to 5 feet increase in sea level by 2100 (most of this is attributable to sea level rise, but geological processes are also causing Rhode Island's coast to slowly sink). About 2,700 housing units in RI fall within three feet above sea level; encroachment and inundation are likely to damage or permanently destroy properties in low-lying areas, as well as other aspects of the landscape.[204] Because of the close relationship between human health and the environment, such infrastructure and environmental damage may have a number of mental health implications.

Because of the important relationship between a sense of place and human well-being, landscape change due to sea encroachment and retreat may produce feelings of distress in affected populations.[205] These emotional effects may exacerbate economic effects arising from migration; for example, insufficient coping may render an individual incapable of maintaining a steady income after the relocation.[206] Current institutional reactions to environmental disruption do not generally take into account our psychological ties with our surroundings, limiting the effectiveness of the response.

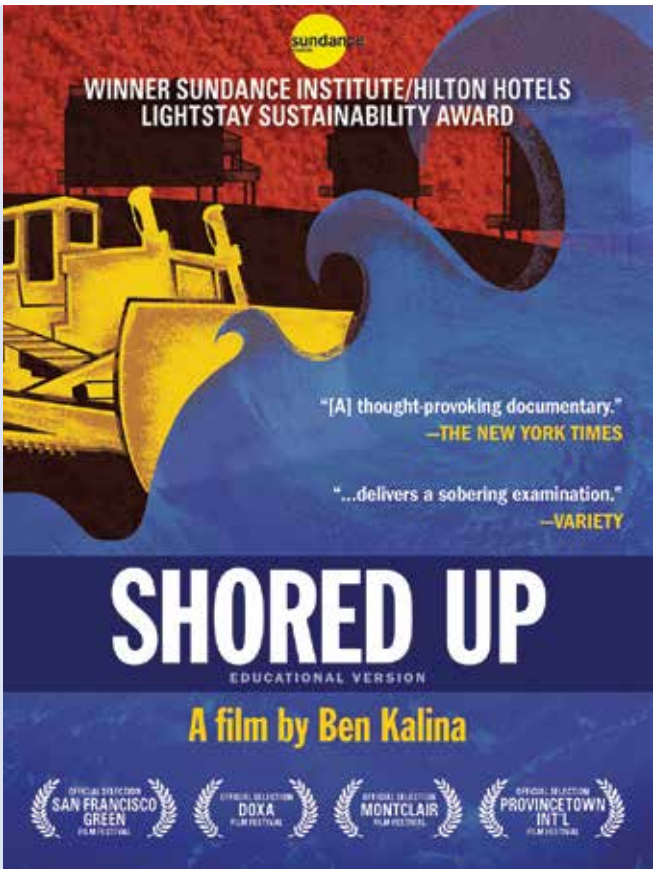
Many families and businesses in Rhode Island may need to relocate, and a managed retreat from the coast may also be necessary. To date, efforts have focused on the physical aspects of relocation rather than the psychological, symbolic, and emotional aspects of relocation.[207] Fullilove (1996) coined the term "rootshock" to describe the psychiatric problems that developed in people displaced by urban renewal in the 1950s and 60s. Although expressions of rootshock may vary between different people and

Shored Up - a Film Documentary

In February 2014, HEALTH's Climate Change Program and Brown University co-hosted a public screening of *Shored Up* and a panel discussion on sea level rise in RI.
The panelists included:

- **Warren Prell – Professor of Geological Sciences, Brown University**
- **Cornelia Dean – Guest Lecturer in Environmental Studies, Brown University and Science Writer for the New York Times**
- **Robert Vanderslice – Team Leader, Healthy Homes & Environment, RI Department of Health**
- **Marilyn Shellman – Town Planner, Westerly Rhode Island**

ABOUT THE FILM: Shored Up is a documentary that asks tough questions about our coastal communities and our relationship to the land. What will a rising sea do to our homes, our businesses, and the survival of our communities? Can we afford to pile enough sand on our shores to keep the ocean at bay? In Long Beach Island, New Jersey and the Outer Banks of North Carolina, surfers, politicians, scientists and residents are racing to answer these questions. Beach engineering has been our only approach so far, but is there something else out there to be explored? Our development of the coastlines put us in a tough predicament, and it's time to start looking for solutions.



communities, displaced people may experience symptoms related to chronic loss and failure, such as anxiety and helplessness depression.[208]

Temperature

Although much of the literature focuses on the effect of acute extreme heat events upon mental health status, gradual temperature rise could also have an effect upon mental health in the region. Several studies have suggested a direct relationship between increasing temperatures, especially prolonged periods of hot weather, and higher rates of aggressive and criminal behavior.[209,210] Excessive core body temperature on a warm day may reduce mental task capacity, and any resulting loss of productivity and income may also cause mental health problems.[211]

Temperature increase may also affect mental health indirectly by acting upon the economic environment. One of Rhode Island's primary industries is agriculture, and farmland covers almost 10% of the state's entire area.[212] Rhode Island is expected to experience significant damages in agriculture with increased temperatures and other climate effects, which may threaten the state's economy.[213] Fishing is also an important part of Rhode Island's economy, and several economically significant species are threatened by climate change.[214] Job loss that results from a decline in the agriculture and fisheries sectors may increase the risk of mental health concerns such as depression, anxiety, decreased self-esteem and life satisfaction.

Drought

Rhode Island's longer, hotter summers are expected to increase drought potential throughout the state.[216] Like temperature rise, the prolonged droughts that accompany climate change may have gradual but profound effects upon population mental health in the region, especially as relates to job loss. Although drought affects large areas and many people, prolonged drought is a disproportionate stressor, affecting rural communities and farmers most severely. Drought may erode the social and economic systems on which rural farming communities depend, increasing the mental health vulnerability of this population.[217] The mental health effects of drought in farming areas can be severe; research conducted in Australia found that the suicide risk for rural males rose 15% in drought conditions.[218]

Vulnerable Populations

While anyone can face mental health impacts due to climate change, certain groups are particularly vulnerable. Poor communities are likely to be disproportionately affected by extreme weather events because of service deficiencies; mental health services may be limited in capacity or exclusionary. Children and adults with pre-existing severe mental health issues are also likely to be affected severely in the aftermath of a natural disaster or an extreme weather event.[219,220] Coastal residents may be particularly vulnerable to mental health effects arising from sea-level rise or hurricanes.[221] Due to the possibility of adverse climate effects on local climate-sensitive industries, individuals employed in these industries may be particularly vulnerable to the mental health effects associated with job loss.

Rhode Island's mentally ill population should be considered especially susceptible to the mental and physical health effects of climate change, as pre-existing mental conditions may increase risk of exacerbated morbidity or mortality during a climate event.[222] However, individuals already receiving care may be resilient to the impacts. Those without support systems may be more at risk.

Individuals who have not yet developed an advanced mental health issue or sought treatment for a mental illness may also be vulnerable. Although mental illness rates in Rhode Island are very high, the rate is derived from numbers of self-reported or provider-reported mental conditions. These individuals or their care-takers are aware of their mental health issues and may be seeking treatment. Those individuals on the margins who are not aware or are not seeking treatment for mental issues may slip through the cracks and not receive suitable care. Climate effects can initiate a mental health disorder or exacerbate an existing disorder, and limited care-seeking and access may prohibit these individuals from receiving treatment.

The aftermath of Hurricane Katrina illustrates this phenomenon. Studies indicate low rates of care-seeking and delivery for mental conditions after the disaster among certain populations.[223,224] Barriers to care originated from several sources, including lack of awareness of mental health and the availability of treatment options, low prioritization of mental health care-seeking, stigma, and relocation of health care providers.[225] Public health interventions should seek to eliminate structural, financial, and attitudinal barriers to mental health care to promote mental well-being in the face of climate threats.[226]

Without a readily available support system, socially isolated individuals and groups may be very vulnerable during and after an extreme weather event. Conditions of social isolation can reduce care-seeking. Therefore, interventions that build social infrastructure and maximize social cohesion may be an effective way to prepare for extreme weather events. Because adaptive capacity hinges upon a community's ability to act collectively, building social capital within the community is vitally important in setting the stage for a public health intervention in response to climate effects.[227]

Best Practices

The Rhode Island Department of Health seeks to better understand and respond to the effects of climate change on mental health and community mental well-being. While the department's Climate Change and Health Project does not have the capacity to conduct wide-spread research, we can look to other states to inform our resiliency-building actions. Using other states' best practices, we seek to propose and implement strategies that promote personal and social empowerment through direct involvement and participation.[228] One of the greatest challenges facing health practitioners may be influencing populations to adopt positive and productive outlooks towards taking collective action to enhance mental health resilience to climate effects. To date, public health interventions to address climatic changes have not focused on mental health and have almost entirely neglected to acknowledge the lived experience of climate change.

Neighborhood Health Stations and Climate Change

A "Neighborhood Health Station" is a model for a new kind of Rhode Island organization that builds community and social cohesion as it supports the health of individuals. By strengthening relationships between healthcare providers, people, and the places they live, work, and play, Neighborhood Health Stations can also help to build community resiliency to climate change.

The model starts with one of Rhode Island's great community health centers or large primary care practices, and adds an expanded staff of health professionals, evening and weekend hours, and facilities for community meetings and physical activity. Every Neighborhood Health Station will base the services it offers on an assessment of community needs, including options ranging from nutrition classes, chronic disease self-management workshops, and safe recreation spaces, to specific staffing that facilitates care for an aging population or a burgeoning number of young children. Funding will support and reward Stations to keep not just their patients, but also the entire community population healthy—sparking outreach efforts to get more people connected with healthcare and to build stronger, healthier, more resilient communities.

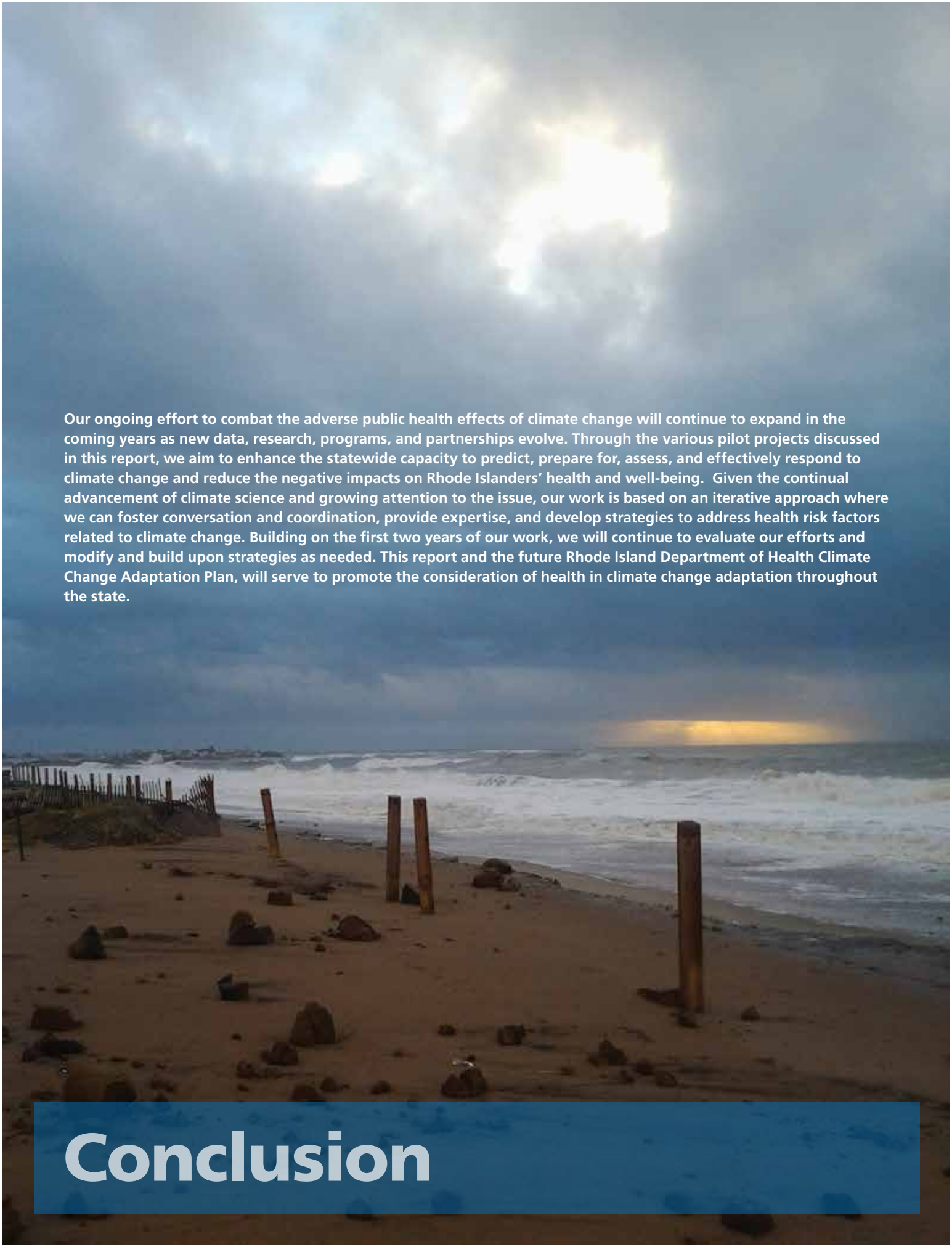
Neighborhood Health Stationsl give community members a voice for making positive changes in their communities and help practices configure themselves to best address local health concerns. These things can help communities grow stronger and better prepared to handle the impacts of climate change. To learn more about Neighborhood Health Stations, see www.health.ri.gov/healthcare/about/neighborhoodhealthstations

Social support and cohesion have been identified as protective factors against post-trauma psychological issues. In a study of the aftermath of Hurricane Floyd in North Carolina, researchers found that high levels of social cohesion and social capital within a community resulted in better and faster recovery after the disaster. Although social capital is generally mobilized on a grassroots level, local and state health departments can coordinate with grassroots-generated efforts to provide resources and assistance. Local public health agencies may promote social cohesion within and among vulnerable communities to maximize resilience to climate effects by organizing capacity-building collaborative community projects. In particular, agencies can facilitate community involvement in project design and implementation to build social capital within the community and between community members and local government.

Integrating a mental health agenda into community emergency preparedness efforts will better prepare health and emergency systems to manage the increased burden of mental illness following a climate-related disaster. Mental health trainings for health care providers, emergency services personnel, and social workers will set the stage for a rapid and effective response to the mental health effects of acute climate events. For example, primary care physicians can incorporate questions relating to the mental health of their patients into consultations in the weeks following a disaster. After Hurricane Sandy, the New York City Department of Health and Mental Hygiene cooperated with Kognito Interactive to create a virtual training for health care providers. The training prepares primary care physicians to identify and manage mental health conditions related to the event. The virtual training can be completed online, and care providers who complete the program are eligible for Continuing Medical Education or Continued Nursing Education credits.

Next Steps

Although previous research on climate change and health has focused on physical aspects of well-being, research indicates that climate change will also have a profound effect upon mental health. Due to the state's unique geographical and demographic characteristics, Rhode Island may be especially vulnerable to certain climate effects and associated mental health burdens. Given the growing threat that climate change poses to mental and physical health in the region, Rhode Island should strive to mainstream climate and mental health considerations within the existing public health agenda, giving special attention to vulnerable groups within the state. Our outreach and work will begin collaboratively. Conversations with the Providence Center, our local community mental health center, will help us to identify needs among their constituents and potential opportunities for training mental health workers on climate change impacts. We will be doing an initial presentation on climate change for their employees and then working with the organization to develop a larger statewide model for other agencies and community members.



Conclusion

Our ongoing effort to combat the adverse public health effects of climate change will continue to expand in the coming years as new data, research, programs, and partnerships evolve. Through the various pilot projects discussed in this report, we aim to enhance the statewide capacity to predict, prepare for, assess, and effectively respond to climate change and reduce the negative impacts on Rhode Islanders' health and well-being. Given the continual advancement of climate science and growing attention to the issue, our work is based on an iterative approach where we can foster conversation and coordination, provide expertise, and develop strategies to address health risk factors related to climate change. Building on the first two years of our work, we will continue to evaluate our efforts and modify and build upon strategies as needed. This report and the future Rhode Island Department of Health Climate Change Adaptation Plan, will serve to promote the consideration of health in climate change adaptation throughout the state.

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Rhode Island Dept. of Health Center for Emergency Preparedness and Response
Rhode Island Dept. of Health Comprehensive Cancer Program
Rhode Island Dept. of Health Asthma Program
Rhode Island Dept. of Health Food Protection
Rhode Island Dept. of Health Beaches Program
Rhode Island Emergency Management Agency
Rhode Island Dept. of Administration
Rhode Island Division of Elderly Affairs
- Long-term care: trade associations, stakeholders, care providers, and more
- Independent elderly: Public Housing Authorities, trade associations, care providers, non-profits, and more

Rhode Island Office of Housing and Community Development
- CDBG- Disaster Recovery program

Rhode Island Office of Energy Resources
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