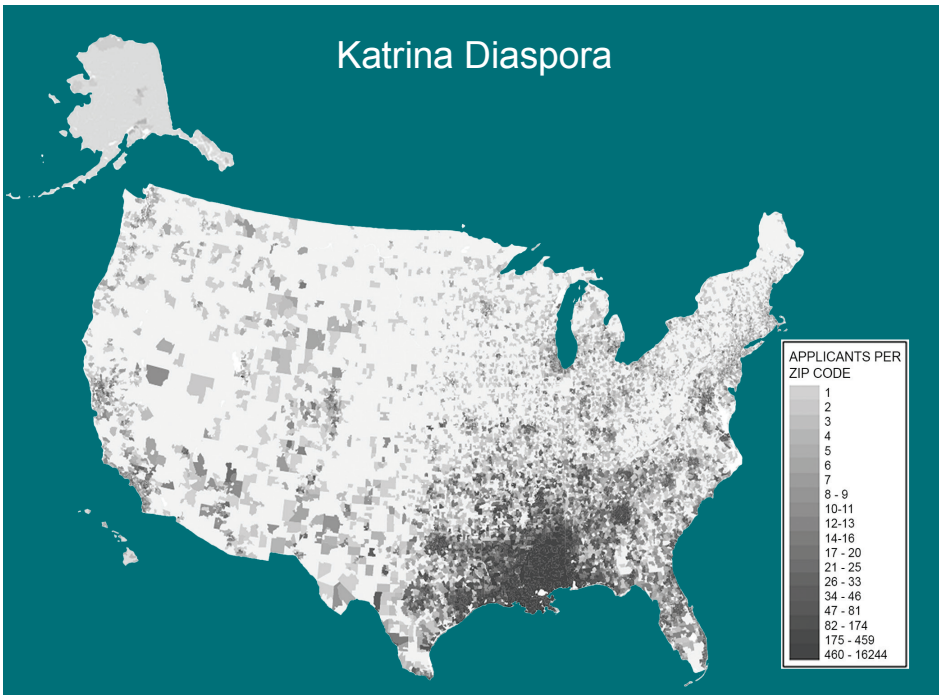
FINDING 4 WIDESPREAD IMPACTS

Impacts related to climate change are already evident in many sectors and are expected to become increasingly disruptive across the nation throughout this century and beyond.

Storm surge on top of sea level rise exacerbates coastal flooding during hurricanes.

Climate change is already affecting societies and the natural world. Climate change interacts with other environmental and societal factors in ways that can either moderate or intensify these impacts. The types and magnitudes of impacts vary across the nation and through time. Children, the elderly, the sick, and the poor are especially vulnerable. There is mounting evidence that harm to the nation will increase substantially in the future unless global emissions of heat-trapping gases are greatly reduced.

Because environmental, cultural, and socioeconomic systems are tightly coupled, climate change impacts can either be amplified or reduced by cultural and socioeconomic decisions. In many arenas, it is clear that societal decisions have substantial influence on the vulnerability of valued resources to climate change. For example, rapid population growth and development in coastal areas tends to amplify climate change related impacts. Recognition of these couplings, together with recognition of multiple sources of vulnerability, helps identify what information decision-makers need as they manage risks.



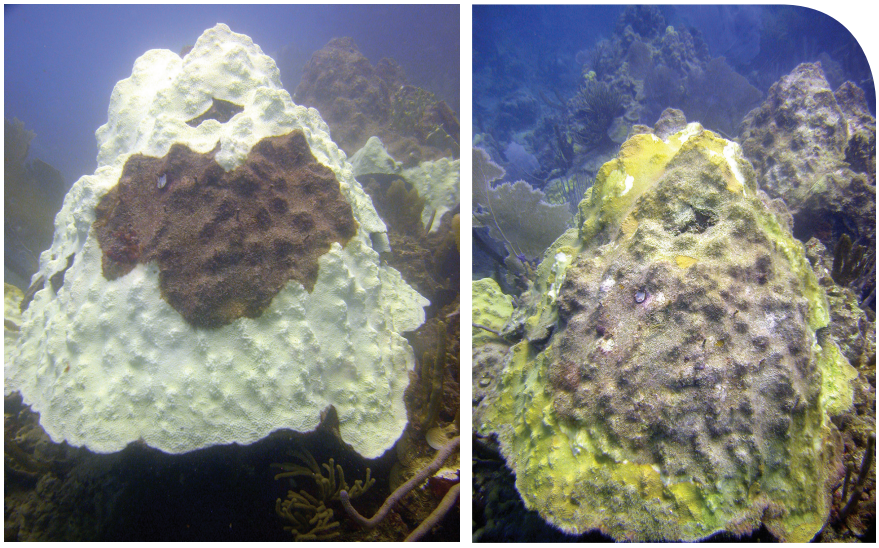
This map illustrates the national scope of the dispersion of displaced people from Hurricane Katrina. It shows the location by zip code of the 800,000 displaced Louisiana residents who requested federal emergency assistance. The evacuees ended up dispersed across the entire nation, illustrating the wide-ranging impacts that can flow from extreme weather events, such as those that are projected to increase in frequency and/or intensity as climate continues to change. (Figure source: Kent 2006[6]).

Multiple System Failures During Extreme Events

Impacts are particularly severe when critical systems simultaneously fail. We have already seen multiple system failures during an extreme weather event in the United States, as when Hurricane Katrina struck New Orleans.[1] Infrastructure and evacuation failures and collapse of critical response services during a storm is one example of multiple system failures. Another example is a loss of electrical power during heat waves or wildfires, which can reduce food and water safety.[2] Air conditioning has helped reduce illness and death due to extreme heat,[3] but if power is lost, everyone is vulnerable. By their nature, such events can exceed our capacity to respond.[4] In succession, these events severely deplete resources needed to respond, from the individual to the national scale, but disproportionately affect the most vulnerable populations.[5]

Coral Reef Ecosystem Collapse

In many social and natural systems, climate change combines with other stresses to cause or expand impacts. For example, coral reefs are threatened by a combination of ocean acidification caused by increased carbon dioxide, rising ocean temperatures, and a variety of other factors caused by human activities.



Warm water caused this coral colony to "bleach" (left) as it expelled the symbiotic algae that gave it color and nourishment. The coral then experienced more disease (right), which eventually killed the colony.

Recent research indicates that 75% of the world's coral reefs are threatened due to the interactive effects of climate change and local sources of stress, such as overfishing, nutrient pollution, and disease.[7] In Florida, all reefs are rated as threatened; with significant impacts on valuable ecosystem services they provide.[8] Caribbean coral cover has decreased 80% in less than three decades.[9] These declines have in turn led to a flattening of the three dimensional structure of coral reefs and hence a decrease in the capacity of coral reefs to provide shelter and additional resources for other reef-dependent ocean life.[10]

The relationship between coral and zooxanthellae (algae vital for reef-building corals) is disrupted by higher than usual temperatures and results in a condition where the coral is still alive, but devoid of all its color (bleaching). Bleached corals can later die or become infected with disease.[11] Thus, high temperature events alone can kill large stretches of coral reef, although cold water and poor water quality can also cause localized bleaching and death. Evidence suggests that relatively pristine reefs, with fewer human impacts and with intact fish and associated invertebrate communities, are more resilient to coral bleaching and disease.[12]

Cascading Effects Across Sectors

Agriculture, water, energy, transportation, and more, are all affected by climate change. These sectors of our economy do not exist in isolation and are linked in increasingly complex ways. For example, water supply and energy use are completely intertwined, since water is used to generate energy, and energy is required to pump, treat, and deliver water – which means that irrigation-dependent farmers and urban dwellers are linked as well.

Heat and drought lead to cascading impacts among sectors including agriculture, water, and energy.

A recent illustration of these interconnections took place during the widespread drought of 2011-2012 when high temperatures caused increased demand for electricity for air conditioning, which resulted in increased water withdrawal and consumption for electricity generation. Heat, increased evaporation, drier soils, and lack of rain led to higher irrigation demands, which added stress on water resources required for energy production. At the same time, low-flowing and warmer rivers threatened to suspend power plant production in several locations, reducing the options for dealing with the concurrent increase in electricity demand.

With electricity demands at all-time highs, water shortages threatened more than 3,000 megawatts of generating capacity – enough power to supply more than one million homes.[13] As a result of the record demand and reduced supply, electricity prices spiked.[14]

FINDING 5 HUMAN HEALTH

Climate change threatens human health and well-being in many ways.

Climate change is increasing the risks of respiratory stress from poor air quality, heat stress, and the spread of food-borne, insect-borne, and waterborne diseases. Extreme weather events often lead to fatalities and a variety of health impacts on vulnerable populations, including impacts on mental health, such as anxiety and post-traumatic stress disorder. Large-scale changes in the environment due to climate change and extreme weather events are increasing the risk of the emergence or reemergence of health threats that are currently uncommon in the United States, such as dengue fever.

Key weather and climate drivers of health impacts include increasingly frequent, intense, and longer-lasting extreme heat, which worsens drought, wildfire, and air pollution risks; increasingly frequent extreme precipitation, intense storms, and changes in precipitation patterns that can lead to flooding, drought, and ecosystem changes; and rising sea levels that intensify coastal flooding and storm surge, causing injuries, deaths, stress due to evacuations, and water quality impacts, among other effects on public health.

Key Messages: Human Health

Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks. Some of these health impacts are already underway in the United States.

Climate change will, absent other changes, amplify some of the existing health threats the nation now faces. Certain people and communities are especially vulnerable, including children, the elderly, the sick, the poor, and some communities of color.

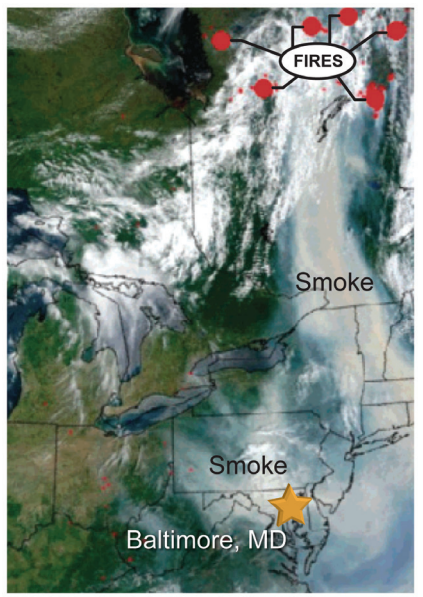
Public health actions, especially preparedness and prevention, can do much to protect people from some of the impacts of climate change. Early action provides the largest health benefits. As threats increase, our ability to adapt to future changes may be limited.

Responding to climate change provides opportunities to improve human health and well-being across many sectors, including energy, agriculture, and transportation. Many of these strategies offer a variety of benefits, protecting people while combating climate change and providing other societal benefits.

Air Quality

Climate change is projected to harm human health by increasing ground-level ozone and/or particulate matter in some locations. Ground-level ozone (a key component of smog) is associated with many health problems, such as diminished lung function, increased hospital admissions and emergency room visits for asthma, and increases in premature deaths.[1] Factors that affect ozone formation include heat, concentrations of precursor chemicals, and methane emissions, while particulate matter concentrations are affected by wildfire emissions and air stagnation episodes, among other factors.[2]

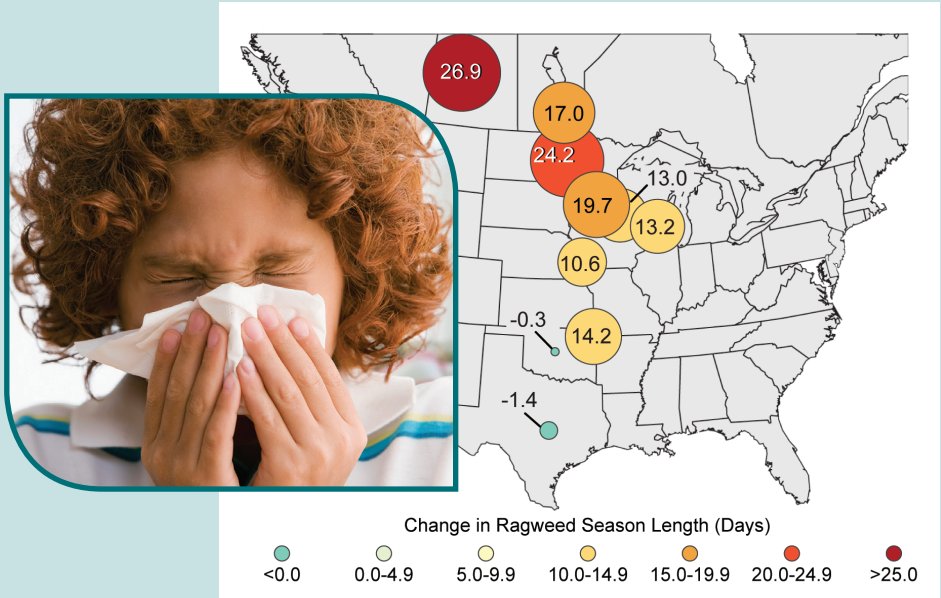
Wildfire Smoke has Widespread Health Effects



Wildfires, which are projected to increase in some regions due to climate change, have health impacts that can extend hundreds of miles. Forest fires in Quebec, Canada, during July 2002 resulted in up to a 30-fold increase in airborne fine particle concentrations in Baltimore, a city nearly a thousand miles downwind. These fine particles are extremely harmful to human health, affecting both indoor and outdoor air quality. An average of 6.4 million acres burned in U.S. wildfires each year between 2000 and 2010, with 9.5 million acres burned in 2006 and 9.1 million acres in 2012.[3] Global deaths from wildfire smoke have been estimated at 260,000 to 600,000 annually.[4] (Figure source: MODIS instrument on the Terra Satellite, Land Rapid Response Team, NASA/GSFC).

Warmer and drier conditions have already contributed to increasing wildfire extent across the western United States, and future increases are projected in some regions.[5,6] Long periods of record high temperatures are associated with droughts that contribute to dry conditions and drive wildfires in some areas.[7] Wildfire smoke contains particulate matter, carbon monoxide, and other compounds, which can significantly reduce air quality, both locally and in areas downwind of fires.[8,9] Smoke exposure increases respiratory and cardiovascular hospitalizations, emergency room visits and medication for asthma, bronchitis, chest pain, and other ailments.[8,10,11] It has been associated with hundreds of thousands of deaths globally each year.[4,8,10,12] Future climate change is projected to increase wildfire risks and associated emissions, with harmful impacts on health.[6,13]

Ragweed Pollen Season Lengthens



Ragweed pollen season length has increased in central North America between 1995 and 2011 by as much as 11 to 27 days in parts of the U.S. and Canada, in response to rising temperatures. Increases in the length of this allergenic pollen season are correlated with increases in the number of days before the first frost. As shown in the figure, the largest increases have been observed in northern cities. (Data updated from Ziska et al. 2011[14]).

Allergies and Asthma

Climate change, as well as increased CO_2 by itself, can contribute to increased production of plant-based allergens.[6,14,15] Higher pollen concentrations and longer pollen seasons can increase allergic sensitizations and asthma episodes,[16,17] and diminish productive work and school days.[14,17,18] Simultaneous exposure to toxic air pollutants can worsen allergic responses.[19] Extreme rainfall and rising temperatures can also foster indoor air quality problems, including the growth of indoor fungi and molds, with increases in respiratory and asthma-related conditions.[20]

Heavy Downpours are Increasing Exposure to Disease

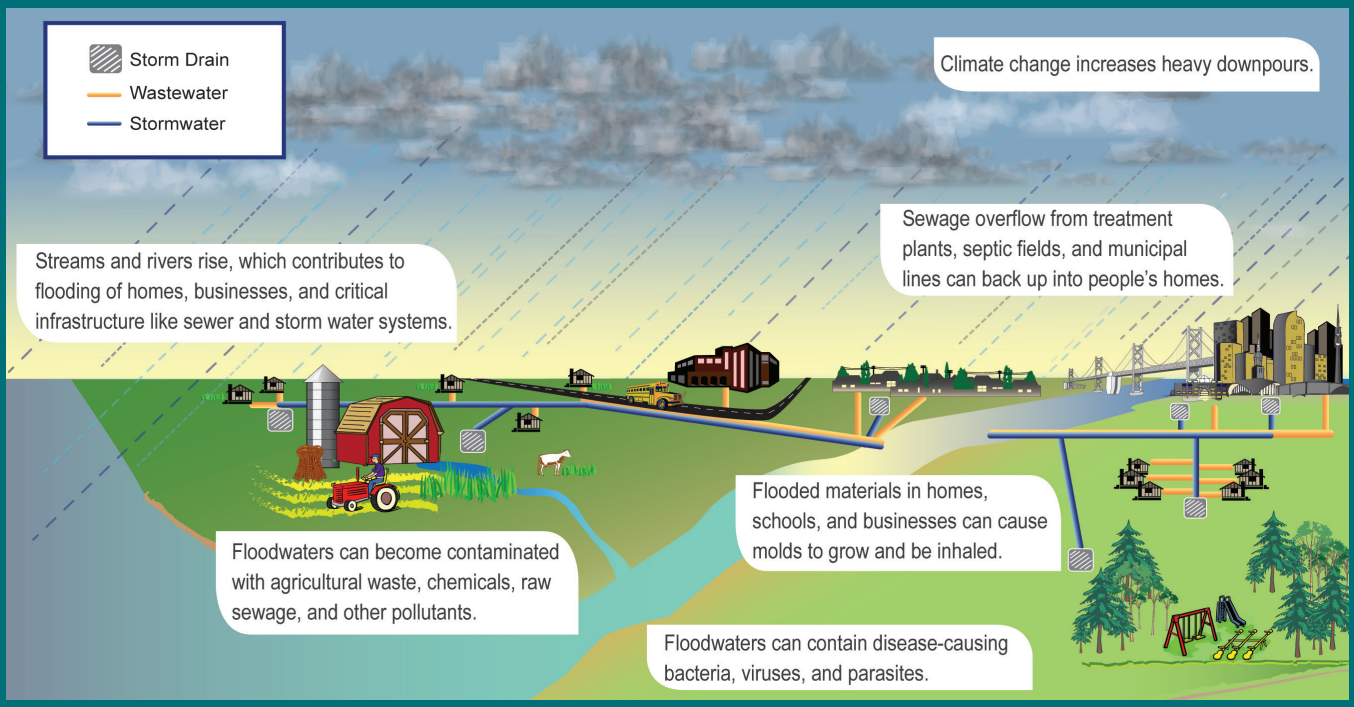


Figure source: NOAA NCDC / CICS-NC

Food and Waterborne Diarrheal Disease

Diarrheal disease is a major public health issue in developing countries and while not generally increasing in the United States, remains a persistent concern nonetheless. Exposure to a variety of pathogens in water and food causes diarrheal disease. Air and water temperatures, precipitation patterns, extreme rainfall events, and seasonal variations are all known to affect disease transmission.[21] In the U.S., children and the elderly are most vulnerable to serious outcomes, and those exposed to inadequately or untreated groundwater will be among those most affected.

In general, diarrheal diseases including Salmonellosis and Campylobacteriosis are more common when temperatures are higher,[22] though patterns differ by place and pathogen. Diarrheal diseases have also been found to occur more frequently in conjunction with both unusually high and low precipitation.[23] Sporadic increases in streamflow rates, often preceded by rapid snowmelt[24] and changes in water treatment,[25] have also been shown to precede outbreaks. Risks of waterborne illness, and beach closures resulting from heavy rain and rising water temperatures are expected to increase in the Great Lakes region due to projected climate change.[26,27]

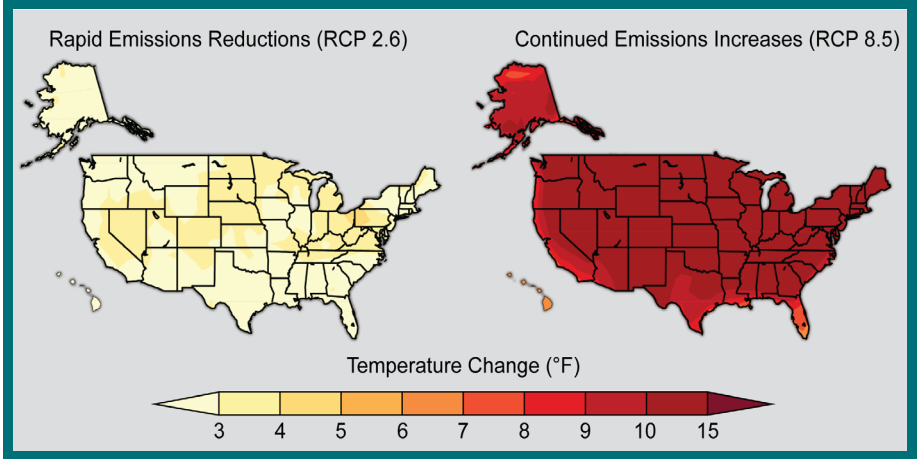
Extreme Heat

Extreme heat events are the leading weather-related cause of death in the United States.[28] Many cities, including St. Louis, Philadelphia, Chicago, and Cincinnati have suffered dramatic spikes in death rates during heat waves. Deaths result from heat stroke and related conditions,[29] but also from cardiovascular disease, respiratory disease, and cerebro-vascular disease.[30,31] Heat waves are also associated with increased hospital admissions for cardiovascular, kidney, and respiratory disorders.[31,32]

Extreme summer heat is increasing in the United States. The effects of heat stress are greatest during heat waves lasting several days or more. As human-induced climate change causes temperatures to continue to rise, heat waves are projected to increase in frequency, intensity, and duration.[33]

Some of the risks of heat-related sickness and death have diminished in recent decades, possibly due to better forecasting, heat-health early warning systems, and/or increased access to air conditioning for the U.S. population.[34] However, extreme heat events remain a cause of preventable death nationwide. Urban heat islands, combined with an aging population and increased urbanization, are projected to increase the vulnerability of urban populations, especially the poor, to heat-related health impacts in the future.[35]

The Hottest Days Will Get Hotter



The maps show projected increases in the average temperature on the hottest days by late this century (2081-2100) relative to 1986-2005 under a scenario that assumes a rapid reduction in heat-trapping gases (RCP 2.6) and a scenario that assumes continued increases in these gases (RCP 8.5). The hottest days are those so hot they occur only once in 20 years. Across most of the continental U.S., those days will be about 10°F to 15°F hotter in the future under the higher emissions scenario, increasing health risks. (Figure source: NOAA NCDC / CICS-NC).

While deaths and injuries related to extreme cold events are projected to decline due to climate change, these reductions are not expected to compensate for the increase in heat-related deaths.[36]

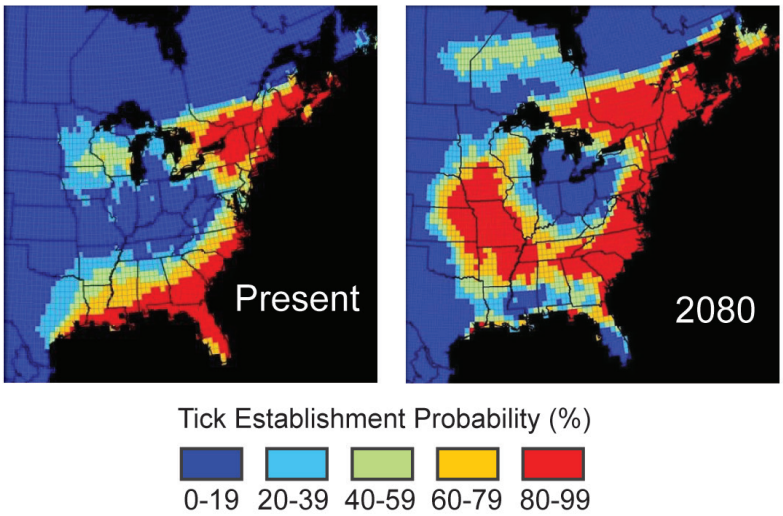
Climate is one of the factors that influences the distribution of diseases borne by vectors (such as fleas, ticks, and mosquitoes, which spread pathogens that cause illness).[37,38,39,40] The geographic and seasonal distribution of vector populations, and the diseases they can carry, depend not only on climate, but also on land use, socioeconomic and cultural factors, pest control, access to health care, and human responses to disease risk, among other factors.[38,41,42]

North Americans are currently at risk from numerous vector-borne diseases, including Lyme, dengue fever, West Nile virus, Rocky Mountain spotted fever, plague, and tularemia.[40,43,44] Vector-borne pathogens not currently found in the U.S., such as chikungunya, Chagas disease, and Rift Valley fever viruses, are also threats. Climate change effects on the geographical distribution and incidence of vector-borne diseases in other countries where these diseases are already found can also affect North Americans, especially as a result of increasing trade with, and travel to, tropical and subtropical areas.[39,42]

Lyme Disease

The development and survival of blacklegged ticks, their animal hosts, and the bacterium that causes Lyme disease, are strongly influenced by climatic factors, especially temperature, precipitation, and humidity. Potential impacts of climate change on the transmission of Lyme disease include: 1) changes in the geographic distribution of the disease due to the increase in favorable habitat for ticks to survive off their hosts;[45] 2) a lengthened transmission season due to earlier onset of higher temperatures in the spring and later onset of cold and frost; 3) higher tick densities leading to greater risk in areas where the disease is currently observed due to milder winters and potentially larger rodent host populations; and 4) changes in human behaviors, including increased time outdoors, which may lead to a higher risk of exposure to infected ticks.

Projected Changes in Tick Habitat



The maps show the current and projected (for 2080) probability of establishment of tick populations (*Ixodes scapularis*) that transmit Lyme disease. The projected expansion of tick habitat includes much of the eastern half of the country by 2080. For some areas around the Gulf Coast, the probability of tick population establishment is projected to decrease by 2080. (Figure source: adapted from Brownstein et al. 2005[46]).

Multiple Benefits

Policies and other strategies intended to reduce carbon pollution and mitigate climate change can often have independent influences on human health. For example, reducing CO_2 emissions through renewable electrical power generation can reduce air pollutants like particles and sulfur dioxide. Efforts to improve the resiliency of communities and human infrastructure to climate change impacts can also improve human health. There is a growing recognition that the magnitude of health "co-benefits," like reducing both pollution and cardiovascular disease, could be significant, both from a public health and an economic standpoint.[47]

Innovative urban design could create increased access to active transport (such as walking and biking).[27] The compact geographical area found in cities presents opportunities to reduce energy use and emissions of heat-trapping gases and other air pollutants through active transit, improved building construction, provision of services, and infrastructure creation, such as bike paths and sidewalks.[48,49] Urban planning strategies designed to reduce the urban heat island effect, such as green/cool roofs, increased green space, parkland, and urban canopy, could reduce indoor temperatures and improve indoor air quality, and could also produce additional societal co-benefits by promoting social interaction and prioritizing vulnerable urban populations.[48,50]