Climate Change

The Importance of Place

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Abstract: Climate change–related risks are place-specific and path-dependent. Accordingly, location is an important determinant of hazardous exposure, and certain places will bear more risk than others. This article reviews the major environmental exposures associated with risky places in the U.S., including coastal regions, islands, the desert Southwest, vectorborne and zoonotic disease border regions, cities, and the U.S. Arctic (Alaska), with emphasis on exposures and vulnerable populations of concern. In addition to these hotspots, this study considers the ways in which the concept of place—the sense of human relationship with particular environments—will play a key role in motivating, developing, and deploying an effective public health response. In considering the importance of place, we highlight the concepts of community resilience and risk management, key aspects of a robust response to climate change in public health and other sectors.

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Introduction, Background, and Scope

Place is one of several dimensions of risk related to harmful environmental exposures. The effects anticipated with climate change will not have a uniform spatial distribution, and place will be a major exposure determinant. As noted by Yohe and Tol,[1] public health threats related to climate change are "location specific and path dependent." Identifying locations where human health risk is heightened can facilitate vulnerability mapping and enhance local public health preparedness, an essential component of adapting to climate change.[2,3]

In addition to location, place also has a different connotation: places are nested collections of human experience, locations with which people and communities have particular affective relationships. People's ties to a place are deep, as is their fealty to traditions that facilitate survival there. Historically, for many societies, this adherence to tradition has complicated adaptation to environmental change.[4] Research shows that an intact relationship with place is fundamental to human health. As Fullilove proposed,

> . . . the sense of belonging, which is necessary for psychological well-being, depends on strong, well-developed relationships with nurturing places. A major corollary of this proposition is that disturbance in these essential place relationships leads to psychological disorder.[5]

Drawing on several different definitions of place, she asserts that place "can be understood as the sum of resources and human relationships in a given location" and that the human sense of belonging to place derives from the psychological processes of familiarity, attachment, and identity.[5] Recent research has validated these propositions: humans exhibit strong place attachment and identity,[6–9] increasing with length of residence.[10] Climate, in particular, is fundamental to the psychological conception of place.[11]

Climate change will disrupt ecologic, cultural, and economic relationships as well as nested conceptions of place. Evaluating climate change's effects on a particular place requires anticipation of these disrupted relationships and their resulting health effects, as well as identification of strategies that may no longer be sustainable in a given place. As a corollary, it will be important to consider the health effects of new adaptive strategies as they are employed in novel environments.

Place-based risk depends on an area's ecology, including climate, and how the location's climate is expected to change. The place's population distribution and characteristics, its major climate-sensitive health problems, and the likely effects on climate-sensitive conditions are also important considerations. Anticipating the ways a shifting climate may complicate and undermine people's relationships with place and divining the health effects of these strained relations are central activities. A deep understanding of all these concerns can drive place-specific public health preparedness.[3]

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As noted, places are nested, overlapping in geographic scale, and defined, to a certain degree, by their relationships with human populations. These aspects of place constrain the following discussion in two ways. First, the current state of climate science allows for coarsely scaled projections. Downscaled projections, in time, will allow for increasingly location-specific consideration of anticipated climate changes in particular places. Given the constraints of coarse resolution, it is best to contextualize the discussion with a brief review of the changes anticipated on a continental scale, perhaps the largest meaningful conception of place for which humans have reference.

Second, given the need to ground a discussion of place in locations that have human particularity, the discussion in this study is limited to the U.S. With its great land mass, extensive coastline, large cities, and geographic variability, the U.S. contains geographic and climatologic prototypes of most places in the world. With regions as varied as Arctic tundra, high and low desert, and tropical islands, a discussion of places at risk in the U.S. will develop globally applicable themes about hazardous exposures associated with climate change and their physical, biologic, and environmental effects on particular environments. Because the U.S. is a wealthy country that brings abundant resources to bear in adapting to climate change, generalizability of specific adaptive measures to other regions of the world may be limited, but the general approach of focusing on place and place-attachment in developing adaptation strategies is transferable.

The most recent review of projections from the UN Intergovernmental Panel on Climate Change (IPCC) reveals a probability >90% that by 2100 North America will warm, with winter warming in the northern latitudes of Alaska and Canada of 10°C (18°F) and summer warming of 4°C (7°F) in the southwestern U.S.[12] Mean annual precipitation is very likely to increase in Can-

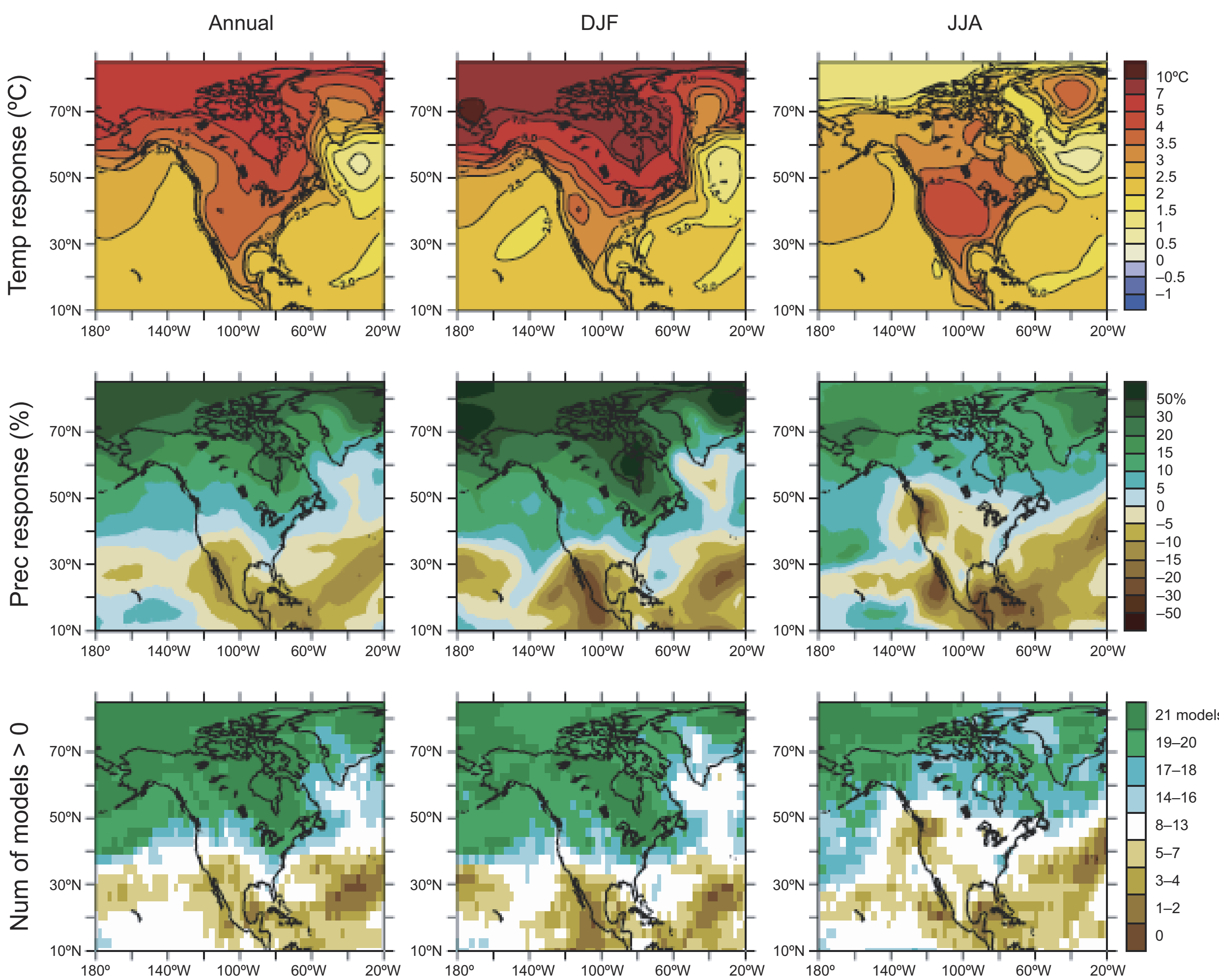

Figure 1. Annual, winter, and summer mean surface air temperature and precipitation increase for North America in 2080–2099 compared to 1980–1999 from MMD-A1B simulation, averaged over 21 models. Bottom row: proportion of 21 models projecting increased precipitation. Excerpted from Christensen, 2007.[12] MMD-AIB is a multi-model simulation with A1B scenario assuming very rapid economic growth worldwide, with peak global population in mid-century, rapid introduction of new and energy-efficient technologies, and balance among various energy sources.
DJF, Dec, Jan, Feb; JJA, June, July, Aug

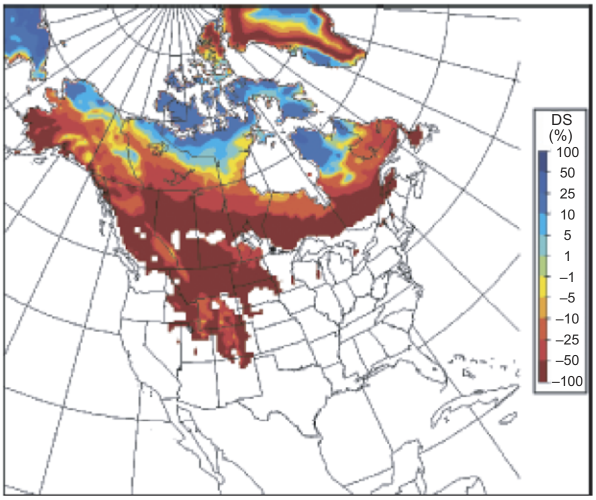

Figure 2. Percent snow depth changes in March projected by the Canadian Regional Climate Model, driven by the Canadian General Circulation Model, for 2041–2070 under SRES A2 compared to 1961–1990. DS, depth of snow (% change); SRES A2, Special Report on Emissions Scenarios, was developed by the Intergovernmental Panel on Climate Change. The A2 scenario assumes a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines (http://sedac.ciesin.columbia.edu/ddc/sres/).

ada and the northeastern U.S., with a likely (>80% probability) decrease in the southwestern U.S. (Figure 1). The length of the snow season and snow depth are both very likely to decrease in most of North America except in the far northern latitudes, where snow depth will likely increase (Figure 2).[12]

Given these changes, places at special risk in the U.S. include coastal areas, river banks and flood plains, islands, drought-prone areas, and arid areas such as the desert Southwest, cities, vector border regions, and Alaska. The following is a review of these places at special risk, with focus on particular exposures of concern and ways in which these places may experience social, psychological, and cultural disruption from these exposures. The conclusion considers appropriate prevention and mitigation efforts.

Coastal Areas

Coastal areas and their unique environmental complexities strain a common definition of place, but nevertheless several common elements exist, including low elevation, the existence of a coastline, and intense human development.

The coastal U.S. includes a narrow fringe an estimated 152,000 km (94,448 miles) in length, and coastal counties in the U.S. constitute 17% of the country's contiguous land mass, with 53% of the population.[13] In 2003, 23 of the 25 most densely populated counties in the U.S. were coastal, and an estimated 153 million people inhabited 673 coastal counties nationwide. Continued migration is expected to increase the coastal population by 7 million in 2008.[14] Given this extensive, heterogeneous habitation, coastal inhabitants share few characteristics on a continental scale, although some regional and local demographic trends are more pronounced.

Ecologically, the coast includes 38,900 km^2 (15,000 miles^2) of wetlands and 6500 km^2 (2500 miles^2) of developed barrier islands.[14] The climate ranges from tropical to arctic. One constant in this diverse ecologic collection, however, is that human development has significantly altered coastal ecosystems, further exacerbating occupants' vulnerability to increasingly frequent storms and the accompanying surge, sea-level change, and other parameters anticipated with climate change.

Coastal populations have several key climate–health relationships, including extreme weather events, sea-level rise, waterborne and foodborne diseases, water table salinity, and ocean acidification. These concerns are likely to threaten infrastructure and strain coastal resources considerably, potentially forcing migration from coastal regions. As with Hurricane Katrina, the decreasing return period of catastrophic weather events is likely to prompt debate on how risk should be conceptualized and distributed, and where redevelopment should be pursued.

Extreme Weather Events

A rise in tropical cyclone intensity has been attributed to elevated sea surface temperatures observed over the past 35 years, particularly around the coastal U.S.[15] Although the long-term data necessary for evaluation of these trends are lacking, the IPCC states that increasingly frequent extreme weather events are very likely.[16]

Hurricanes are associated with several adverse health effects. Mortality in the initial event is due primarily to trauma secondary to wind-strewn debris and structural collapse and from drowning in storm surges and flash floods. In the preparation and clean-up phases, deaths occur from electrocution and from carbon monoxide poisoning from generator use.[17] Morbidity from extreme events includes nonfatal injuries and near-drowning. Chronic disease exacerbations take a considerable toll, as displacement creates physical and mental stresses, affects coping abilities, and limits healthcare access. Extreme weather events also increase risks for long-term mental health issues, including post-traumatic stress disorder and respiratory illnesses associated with damp indoor environments.[18,19] Finally, the risks for disease transmission may increase where a particular disease is endemic; risks may also intensify in densely populated shelters with compromised sanitation and hygiene.[20]

Hurricane Katrina serves as a case study of the complex, durable health and social effects of a catastrophic weather event on coastal residents. Katrina made landfall in Louisiana on August 29, 2005, and by September 5, a total of 229,338 Gulf Coast residents had been displaced into evacuation centers in Louisiana and several surrounding states.[21] Morbidity and mortality related to Katrina followed patterns similar to those described above: Evacuation centers saw 14,531 visits for health problems, with chronic disease exacerbations the leading reason for seeking care. Visits to healthcare facilities totaled 9772 and were most commonly for injuries.[21] The total number of direct and indirect deaths associated with Hurricane Katrina stands at 1836.[22,23] As the costliest and most destructive hurricane ever to hit the U.S., Katrina highlights the difficult issues related to displacement, resettlement, and the fierce debate, fueled largely by intense connections to place, over redevelopment where there is increasing risk and a diminishing resource base.[24,25]

Sea-Level Rise

Sea levels have been rising for decades, secondary to thermal expansion, at a rate of 2 mm (0.08 in)/year over the last 50 years.[26,27] In future decades, this rise will increase to 3 mm (0.12 in)/year because of the melting of land-based ice, compounding the expansion effect. Although predictions are complicated by uplift and land subsidence, other estimates indicate an increase of 1.5 to 3.5 times over historic rates.[28] In the next 100 years, sea levels are expected to rise 10–89 cm (4–35 in), in contrast to a rise of 10–20 cm (4–8 in) observed in the past century.[14,16] Sea-level rise threatens low-lying infrastructure—in the U.S., the city of New Orleans is built below sea level. In fact, 14 of the 20 largest cities in the U.S. are built on coastal zones, and sea-level rise may overwhelm geographic and ecologic barriers that protect human settlements from extreme weather events.[14]

Rising sea levels pose several threats, including worsening storm surge, infrastructure damage, and erosion. There is concern for the direct impacts on water utility infrastructure: Intakes in brackish areas may be impaired by changing sedimentation patterns resulting from natural wave action, storm surges, and flow conditions, leading to changes in water quality and quantity.[29] Rising sea levels also can cause intrusion of more dense saltwater into coastal aquifers.[29] In many locations along the Eastern seaboard in the U.S. and the Netherlands, saltwater intrusion has already resulted in groundwater contamination.[29–32] The U.S. Environmental Protection Agency (EPA) has found that water resource managers must consider in their planning processes this outcome of climate change in the context of other stressors.[30]

Rising sea levels also lead to shoreline erosion, increasing the vulnerability of infrastructure, dwellings, and their inhabitants to coastal hazards.[31] According to one prediction, over the next 60 years, one of four houses within approximately 150 m (492 ft) of the U.S. shoreline will be adversely affected by erosion.[31] Shoreline erosion also alters coastal agriculture, coral reefs, marine ecosystem health, and ecosystem functions. In coastal wetlands, these changes affect water purification, flood and drought mitigation, and the generation of fertile soils, with ramifications for water quality and food production.[14] In certain communities, inexorable erosion forces land-use changes, including reinforcement, retreat, or abandonment. Communities sometimes employ radical measures—for example, importing large quantities of sand to shore up eroding beaches—to maintain their sense of place, their primary economic activities, and their infrastructure in the face of growing threats.[33]

In coastal areas where land use has resulted in considerable wetland loss and net land subsidence (sinking or gradual settling of land), such as in Louisiana, increasingly frequent extreme weather events, sea-level rise, and erosion all pose significant questions about future land use, development, and disaster relief decisions. Current development patterns, including the federal National Flood Insurance Program, the structure of federal disaster assistance through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, federal tax subsidies for seasonal second homes, and numerous state and local infrastructure programs promote development in areas with known, and demonstrably increasing, risk.[14] This development creates important human vulnerability and begs the question of how this risk should be distributed on a local, regional, national, and potentially international scale.

Waterborne and Foodborne Diseases

Coastal waters harbor pathogens that may proliferate under ideal conditions: Sunlight, pH, ocean and wind currents, sea surface temperatures, and sewage runoff all affect growth rates and persistence, and several of these variables are likely to be affected by climate change.[16] In particular, acute viral, bacterial, and parasitic gastroenteritis can become epidemic in the right conditions. Harmful algal blooms, formed when conditions are right, produced by certain algal species such as phytoplankton, can release toxins that cause debilitating illnesses in humans through bathing or ingestion.[34] Fish and shellfish can release biotoxins, resulting in ichthyohemotoxism, ichthyoototoxism, or ichthyosarcotoxism when the fish or shellfish are consumed. Two examples are the disease ciquatera and the fish tetradon. An outbreak in 2004 of *Vibrio parahaemolyticus* associated with seafood harvested in Alaska extended the northern range of the pathogen by 1000 km (620 miles).[35] Many of these hazards have a relatively low prevalence, and the anticipated changes in incidence are small, but some diarrheal diseases are quite prevalent. Small changes in their incidence can affect large numbers of people.

Ocean Acidification

Ocean acidification, resulting from increased absorption of atmospheric carbon dioxide (CO_2) into the oceans, poses a severe threat to marine organisms with calcium carbonate in their bodies and shells.[36] Acidification, which is anticipated to accelerate over the century, will be most marked in polar regions. It could result in collapse of certain ocean ecosystems, severely compromising food supplies for coastal communities heavily dependent on seafood. Coral reefs will also be at risk, with projections suggesting that unmanageable deterioration of most tropical coral reefs will occur when the atmospheric CO_2 concentration is $>$500 parts per million (ppm).[36] This deterioration will result in a cascade of effects,[37] including the collapse of fisheries, tourist economies, and the reef's protection from ocean storms and erosion.[36,38,39] Absent aggressive mitigation efforts and adaptation activities, ocean acidification poses a fundamental threat to certain coastal communities on par with that of a sea-level rise.

Islands

In the U.S., more than 5.5 million people live on thousands of islands, including a state and several territories (Hawaii, Puerto Rico, Guam, the U.S. Virgin Islands, American Samoa, and the Northern Mariana Islands).[40] These island communities, by definition coastal, will face the same stressors as their counterparts in the contiguous North American continental land mass. In addition to characteristics common to the coasts, islands are relatively physically isolated. They are dependent on imported goods and services, have limited freshwater resources, and have relatively high costs for food, energy, and infrastructure maintenance. Finally, they are particularly vulnerable to external shocks in world economic conditions.[41] All of these characteristics amplify the risk from climate change.

Sea-level rise is perhaps an islands' most significant threat. On many islands, housing, agricultural land, and infrastructure, including roads, airports, critical care facilities, and tourist resorts, are located in such a way that inundation by only 60–90 cm (2–3 ft) would lead to the need for emergency response and long-term recovery. Sea-level rise also leads to impaired crop production, damage to coastal ecosystems, and population displacement, all of which may produce additive or synergistic effects when combined with other stressors.[42] These acute stressors precipitate long-term concerns: coastal erosion, water and soil salinization, and loss of arable land ultimately affect cash crop exports and represent a long-term economic hazard.

Extreme weather events pose serious risks that act synergistically with sea-level rise. Of all the islands in the U.S., those in the Caribbean face the largest relative increase in flood risk.[42] Changes from large interannual climate cycles, such as the El Niño Southern Oscillation (ENSO), may produce flooding in some areas and drought in others. The 1997 ENSO led to storms as well as severe drought in Micronesia.[43] Where drought was extreme, micronutrient deficiencies were identified in pregnant women in Fiji.[43] Heat-related illnesses, chronic disease exacerbations, and mental health are also concerns.[44–46] Finally, damage to fragile ecosystems, coral reefs, and coastal fisheries can compromise food supply, compound stress from ocean acidification, hobble the tourist trade, and deplete vulnerable terrestrial food sources.[46]

Environmental hazards represent profound challenges to island ecology and the function of island communities. In some cases, this strain will result in the dislocation of island populations. Although not in the U.S., the archipelago of Tuvalu serves as an extreme example. Its citizens became the world's first environmental refugees from climate change when the government began relocating the entire nation secondary to sea-level rise and inexorable stress on water treatment and other infrastructure. Its freshwater tables have become brackish and poisonous for growing dietary staples, straining food resources to the breaking point and forcing permanent evacuation.[26]

The Desert Southwest

Exemplifying the fact that climate change will bring about greater extremes, we focus next on the desert in the southwestern U.S. Geologically termed the Great Basin or the Basin and Range, the area is a large, arid region bordered to the west by the Sierra Nevada and the east by the Colorado Plateau (Figure 3). It is home to characteristic flora and fauna. It has relatively sparse rainfall in typical years. Much of the region is high desert, with elevations from 1.2 to 3.7 km (0.75–2.29

Figure 3. The Basin and Range province and contiguous geologic zones. Courtesy of U.S. Geological Survey.

miles). The Great Basin is unusual in that it is endorheic, with no drainage to the sea. Of note, many of the communities in the states surrounding the Sierra Nevada and the Rockies depend on mountain snowmelt for their water and, in many cases, for hydroelectric power.[47]

Human habitation in the Southwest is characteristically sparse, with a population density under 3 people/km^2 (8 people/$mile^2$), with the exception of several large and fast-growing metropolitan areas such as Phoenix AZ and Las Vegas NV. Human ecology in this region is heavily influenced by water availability, and water rights are governed by complex pacts dating to the initial period of westward expansion.[48–52] Currently, approximately 90% of the West's water is devoted to agricultural activities.[47]

Under the anticipated climate regime, the Southwest will warm and its precipitation patterns will change. The climate of the Western U.S., including the Southwest, is expected to enter a permanent state more consistent with the now relatively infrequent ENSO.[52] The ENSO typically brings greater rainfall to the Southwest, although in certain areas average rainfall is reduced in ENSO years.[53] Precipitation is expected to increase moderately during the winter months and decrease significantly during the summer, for a net minimal decrease in annual precipitation.[12] This net minimal decrease is deceptive, however, as overall the region is predicted to experience severe water stress.[47]

Regional climatic changes are expected to change the distribution and frequency of certain human disease exposures. Heat exposure will increase, particularly for vulnerable populations in urban areas, where the urban heat island effect is most pronounced.[2] There may be associated changes in respiratory and cardiovascular disease exacerbations secondary to heat, ozone exposure, and increased particulate emissions from power generation to supply air conditioning demands.[2,54] Drought, which affects more North Americans on a population basis than any environmental hazard,[55] may precipitate water shortages and necessitate careful, aggressive management of water use.[56] However, the medical literature reports no interruptions in the potable water supply as a result of drought in developed countries. More likely than drinking water shortages are economic impacts as water is diverted from farming and industry for human consumption; this effect would be most pronounced in areas with heavy economic reliance on agricultural activities[47] and in areas with heavy reliance on winter snowmelt for their water supplies. There may be health effects of novel strategies for water collection, storage, and purification as large municipalities face increased water scarcity,[57,58] and people relying on wells and small water treatment systems may be at increased risk of waterborne disease from extreme precipitation events,[59] although such events are rare in the region.

Also of particular interest in the Southwest are vectorborne and zoonotic diseases. Some vectorborne diseases in the region, particularly plague, are climate-sensitive, and their incidence may be affected by climate change; these diseases are discussed at great length by Gage and colleagues[60] in this issue, and they are not addressed here. Also of concern is the possibility of increasingly prevalent hantavirus cardiopulmonary syndrome (HCPS) secondary to increased rainfall. The Sin Nombre hantavirus, the strain that caused the 1993 Four Corners outbreak, circulates in local populations of deer mice; the deer mouse population is positively correlated with winter and spring precipitation, and it has a demonstrated association with ENSO events.[53,61] With increased precipitation in the winter, there is concern that permanent alterations in deer mouse ecology will result in more frequent human Sin Nombre virus infection and the resultant HCPS, which has a case fatality of approximately 35%.[62] However, the effects of increased climate variability and long-term change on deer mouse ecology and HCPS incidence are very difficult to project, given the disease's complex ecology.

Border Regions of Vectorborne and Zoonotic Disease

A warming world will see movement of ecologic transition zones, boundaries of different populations of characteristic flora and fauna influenced by topography and climate. The implications for human health will be apparent in places where these movements result in changing infectious disease ecology, from changes in the range of arthropod vectors and zoonotic hosts. This topic is covered extensively elsewhere in this issue,[60] but it bears mention here as well. Although not anticipated to be a major public health problem in the U.S., several disease vectors may extend their ranges in the U.S., and it is possible that the incidence of associated vectorborne diseases may increase as a result.

For instance, climate change may expand the range of Lyme disease, an arthropod-borne disease spread by nymphal *Ixodes scapularis* ticks infected with the spirochete *Borrelia burgdorferi*.[63] Figure 4 shows the current range of suitable locations for *I. scapularis* in the U.S., as well as projected shifts in range under climate change.[64] The ecology of Lyme disease is incompletely understood, although there is evidence that an abundance of acorns, as well as winter temperatures and precipitation, with a 1- to 2-year lag structure, significantly affect the prevalence of infected vectors.[65,66] The impact of these changes on human disease incidence has not been fully evaluated, but there is clearly potential for climate change to shift the places in which certain vectorborne and zoonotic diseases are prevalent.

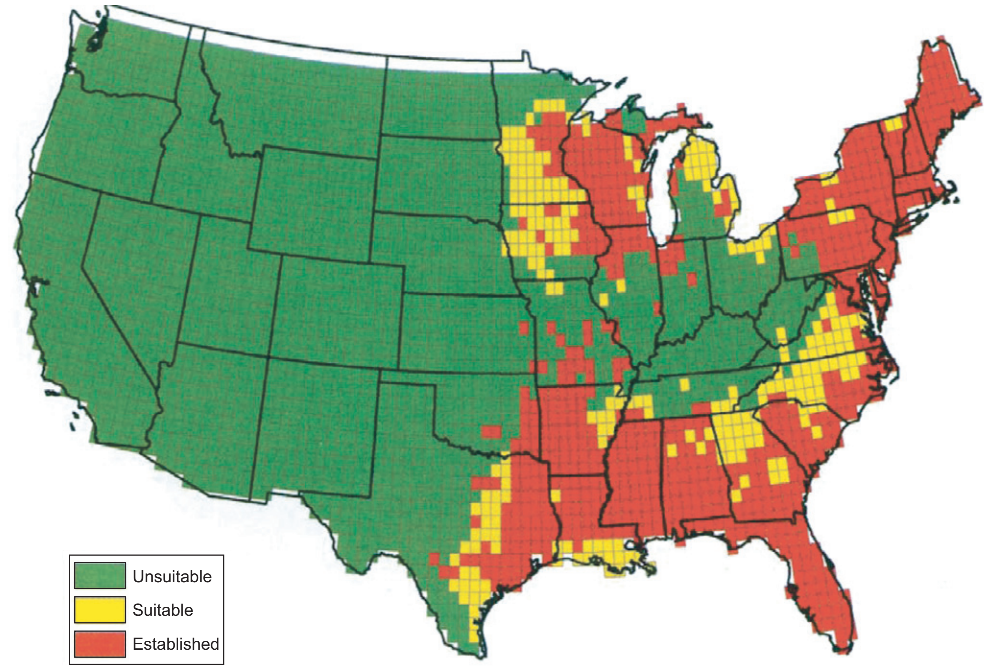

Figure 4. Range of suitable conditions for *Ixodes scapularis*, the Lyme disease vector. As the climate warms and there is increased precipitation in the northern latitudes, *I. scapularis*'s range is expected to expand northward (yellow areas indicate projected suitable habitats).

Cities

Cities and, in a larger sense, the built environment are major components of place. Again, while this topic is covered more extensively by Younger and colleagues[67] elsewhere in this issue, it bears mention, as people in cities—and certain populations and places within cities—are at special risk from climate change. Urban dwellers face heightened risk for a host of exposures, including heatwaves, air pollution episodes, and floods.[68] In particular, the urban heat island effect will intensify heat exposure, leading to increased heat-related illness among urban dwellers. Projections for the New York City region through the 2050s suggest that there will be a net increase in heat-related premature mortality in the metropolitan region.[54]

Other harmful exposures more prevalent in urban environments, including airborne pollution and ozone, which amplifies the positive correlation between temperature and cardiovascular mortality, will both increase as a result of climate change.[69] While urban environments can be modified to mitigate the effects of climate change, and novel building practices can minimize emissions and maximize resilience in the face of disasters,[70,71] urban areas are still likely to concentrate unhealthy environmental exposures. Particularly vulnerable populations include the very young and the very old, outdoor laborers, athletes, pregnant women, those with chronic respiratory and cardiovascular diseases, those on certain medications, the socially and physically isolated, and those of lower SES. The likely extent of the increased burden of disease from these exposures on particular risk groups is unclear.

U.S. Arctic (Alaska)

In the U.S., climate change will perhaps be most pronounced in Alaska, a lightly populated state one fifth the size of the lower 48 states combined. Alaska's ecology and demographics are both distinct from those of the lower 48 states, and its climate–health dynamics are also different. Although climate change will bring a host of new stressors to the region, it will also bring relief from certain health risks as well as access to new economic opportunities. The net balance of both direct and indirect effects is difficult to forecast. Regardless, it is clear that climate change will result in considerable economic and cultural upheaval, particularly for Alaska Natives, an already vulnerable population.

One sixth (116,000) of Alaska's population is Alaska Native, living mostly in small isolated communities scattered along coastal regions and rivers that provide ready access to subsistence hunting and fishing. Life expectancy at birth for Alaska Natives is 69.4 years, compared to 76.7 years for all U.S. races. The Alaska Native age-adjusted unintentional injury mortality rates are 3.3 times the rate for all U.S. races, and the suicide mortality rate is 4.2 times the all-races U.S. rate.[72] Of the Alaska Native population, 25.7% live below the poverty level, and many still depend on a subsistence lifestyle of hunting and fishing. Perhaps more than most populations referenced in this discussion, Alaska Natives are uniquely vulnerable to the changes from increased climate variability and long-term change because of their close relationship with the land and the sea.

The direct health effects of climate change in this region will result from changes in ambient temperature, altered patterns of risk from outdoor activities, and changes in the incidence of infectious disease. As ambient temperatures increase, the incidence of hypothermia and associated morbidity and mortality should decrease. Conversely, hyperthermia may increase, particularly among the very young and elderly, although this change is likely to be negligible. More significantly, unintentional injury, already the second major cause of mortality among Alaska Native men and the third among women, may increase.[73] The reduction in river and sea-ice thickness, curtailed ice season, reduced snow cover, and permafrost thawing will all make hunting and gathering more difficult, dangerous, and less successful, thereby increasing the chance for injuries and drowning.

Several infectious diseases are known or are postulated to be temperature-sensitive and likely to increase in prevalence in a warming Arctic.[74] The incidence of foodborne gastroenteritis from *Shigella* and *Salmonella*, as well as from toxins produced by *Staphylococcus aureus* and *Clostridium botulinum*, and certain seafood-related diseases, including those from *Vibrio* species and paralytic shellfish poisoning, will all potentially be affected.[34] Waterborne diseases, including *Entamoeba histolytica, Giardia lamblia, Cryptosporidium parvum, and Echinococcus* species, are likely to become more prevalent as the range of animal hosts extends northward[75]; the same is predicted for rabies.[76] Vector-borne diseases such as West Nile virus and other arboviruses, such as that causing equine encephalitis, may extend their ranges northward as well. Specific stages of the lifecycles of many helminths and arthropods may be greatly influenced by temperature, where small changes can substantially alter the transmission of lung worms and muscle worms pathogenic to such land mammals as caribou, muskoxen, thin-horn sheep, and moose—all important subsistence species for Alaska Natives.[77]

Indirect health effects may well be more extensive and disruptive. Climate change will bring fundamental changes in the way land is used, infrastructure protected, and natural resources accessed.

In particular, warming will reduce the extent of ice, fundamental to human settlement and Arctic ecosystems alike. Ice-rich permafrost currently underlies most of Alaska, supporting entire communities. The recent decades of warming have been accompanied by extensive permafrost thawing in many areas, causing river bank erosion, ground subsidence, and damage to community buildings and infrastructure. Particularly concerning from a health perspective, the damage to water intake systems resulting from the thawing can allow contamination of the water supply; thawing can also damage access roads, water storage tanks, and wastewater treatment facilities, rendering water and wastewater treatment systems inoperable.[78]

Reductions in sea ice pose other challenges. In 2007, Arctic sea-ice cover reached the lowest extent recorded since observations began in the 1970s, exceeding the most pessimistic model predictions of an ice-free Arctic by 2050. Although experts may debate the import of this nadir, it is clearly a harbinger of changes in marine ecosystems, coastal climate, human settlements, and subsistence activities across all regions of the Arctic. The sea-ice retreat will increase marine transport and access to vast oil, gas, and mineral reserves. Tourism will increase, as will public-sector services to support the expanded oil, gas, and mineral economies.

These new ventures will bring employment opportunities, but they will also affect population distribution and challenge the traditional subsistence way of life for many communities, confusing fundamental relationships with place. Reduction in the traditional food may lead indigenous communities to depend increasingly on nontraditional Western foods, resulting in increasing rates of health problems associated with processed foods, including obesity, diabetes, and cardiovascular diseases, and foodborne infectious diseases associated with imported fresh and processed foods.[79] This effect may be mediated by increasing local agricultural production as the growing season lengthens.

Other indirect health effects may result from dislocation. Dislocated families and communities will have to adapt to new ways of living, may face unemployment, and will have to integrate and create new social bonds. Relocation may also lead to rapid loss of traditional culture, exacerbating stressors and mental health challenges. The stress of acculturation to new adoptive communities can be lonely and difficult, precipitating depression, anxiety, substance abuse, and suicidality.[80] A positive result can be opportunities provided by relocation. Greater access to education, employment, health care, and less expensive foods, including fresh fruits and vegetables, may contribute to improved overall health for individuals and communities that manage the transition well.

Climate Change, Disconnection, and Displacement

Many of the exposures discussed above, including sea-level rise, movement of ecologic transition zones, and economic strain on regions and communities, are likely to complicate and undermine human relationships with place. Climate change will affect these relationships by prompting migration or by fundamentally altering a place's ecology such that established human relationships with place can no longer be maintained.

As noted in the Introduction, disruption of place attachment and identity are traumatic for the individual and collective psyche, and rupture of the strong bonds humans have with place has detrimental health effects at the individual and community levels. Dislocation and displacement, ranging from increased mobility within a given locale to forced emigration, compromise mental health.[81–84] In addition, disasters and other events that fundamentally alter the ecology of a given place disrupt people's attachment to place and identity, precipitating culture loss, even if inhabitants are not physically displaced.[85,86] More subtly, and on a collective level, displacement undermines a community's capacity to engage various threats. Hughes[87] first observed that the rupture of the person–place bond compromises community engagement and resilience, a key concept in disaster response and ecologic recovery.[88,89]

Just as disruption of place attachment compromises both individual mental health and community health, a strong, intact place attachment is an important component of environmental concern and involvement. Place attachment and place-related social identity are associated with attitudes toward sustainability and concern for local environmental issues.[90,91] When combined with local social connection, place attachment is a significant predictor of civic involvement.[92] Thus, place attachment is an important variable in public health planning for environmental threats, as it is a driver of concern and, when disrupted, a threat to community resilience.

The Public Health Value Added By Emphasizing Place

The public health response to climate change has been discussed at length previously, and several frameworks have been proposed, including the Essential Public Health Services[93] and the familiar framework of primary, secondary, and tertiary prevention, expanded on by Ebi and Semenza[94] in this issue. Place does not currently have a formal role in these frameworks, and much can be said for the importance and strategic worth of a coordinated national and international plan that pools resources and widely distributes risk. Nevertheless, incorporating an emphasis on place adds several practical advantages to a broad approach to adaptation generally[3] and public health adaptation specifically.

In particular, a focus on place emphasizes the local nature of both exposures and response, and it brings attention to environmental changes where the motivation to address them is strongest: Emphasizing place highlights climate change's effects where they are most acutely felt, where local strengths are best understood, where place attachment can be leveraged most effectively, and where residents will reap the benefits of adaptive measures promoting sustainability and livable communities. Emphasis on place also forces an examination of risk and how it is distributed regionally, as it is often pooled on a regional basis, either explicitly or by virtue of the regional networks developed to deal with adverse events. In many locations around the world, the risk of injurious exposures from climate change is inversely proportional to adaptive capacity, an important issue for public health preparedness.[95] Finally, a focus on place and the importance of the local response recognizes the importance of municipal, state, and regional political processes in preparation and response activities, thereby enhancing ecologic and community resilience.

These strategic advantages are evident when one uses the Essential Public Health Services framework. Table 1 illustrates the value added by considering place when anticipating public health needs related to climate change.

These essential functions must be pursued at many levels concomitantly. It is always important, however, to bear in mind that many of climate change's most grievous health effects will be felt locally, and that local

Table 1. Public health value added by focusing on place

Essential public health service	Value added by focusing on place
Monitor health status to identify and solve community health problems	Local monitoring of hantavirus and plague in the desert Southwest, and local knowledge of disease eco-epidemiology; anticipation of health problems resulting from displacement
Diagnose and investigate health problems and health hazards in the community	Local detection and investigation of waterborne disease outbreaks after extreme precipitation events in cities with combined sewer systems
Inform, educate, and empower people about health issues	Locally derived and managed municipal heat wave response plans
Mobilize community partnerships and act to identify and solve health problems	Partnerships between local interest groups and city planners to increase options for walking and cycling
Develop policies and plans that support individual and community health efforts	Local disaster preparedness activities in coastal areas
Enforce laws and regulations that protect health and ensure safety	Local enforcement of rules and regulations related to clean water, food safety, and sanitation
Link people to needed personal health services and ensure the provision of health care when otherwise unavailable	Regional public health preparation for service continuation and evacuation after extreme weather events in populous coastal areas
Ensure competent public and personal healthcare workforce	Local emergency manager training to apply all-hazards approach to health effects of climate change in a particular region
Evaluate effectiveness, accessibility, and quality of personal and population-based health services	Awareness of vulnerable and geographically isolated populations, such as Alaska Natives, in evaluating efficacy of targeted prevention services
Research for new insights and innovative solutions to health problems	Local research into building material properties and contribution to heat island in warming cities

ties and local resilience—a sense of place—will be central to an effective response.

Conclusion

Climate change will bring potentially injurious exposures to human communities the world over, although certain places and the communities they nurture will be at particular risk. Identifying places at special risk from climate change is a complex exercise in human ecology. Given the changing exposures that we know climate change will bring, we can identify places where human populations and critical infrastructure will be at particular risk. Identifying these places and highlighting these exposures are key aspects of risk identification, which in turn is fundamental to risk distribution. Risk management is emerging as a central tenet of the climate change response, in public health as well as other sectors. A focus on place promotes resilience, which is central to maintaining public health.

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References

1. Yohe G, Tol RSJ. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Glob Environ Change 2002;12:25–40.
2. Patz JA, Kovats RS. Hotspots in climate change and human health. BMJ 2002;325(7372):1094–8.
3. Yohe G, Schlesinger M. The economic geography of the impacts of climate change. J Econ Geogr 2002;2:311–41.
4. Diamond J. Collapse: how societies choose to fail or succeed. New York: Viking, 2005.
5. Fullilove MT. Psychiatric implications of displacement: contributions from the psychology of place. Am J Psychiatry 1996:1516–23.
6. Altman I, Low S. Place attachment. New York: Plenum, 1992.
7. Brown B, Perkins D. Disruptions in place attachment. Human Behav Environ Adv Theory Res 1992;12:279–304.
8. Stedman R. Toward a social psychology of place: predicting behavior from place-based cognitions, attitude, and identity. Environ Behav 2002;34: 561–81.
9. Giuliani MV. Theory of attachment and place attachment. In: Bonnes TL, Bonaiuto M, eds. Psychological theories for environmental issues;137–70. Aldershot: Ashgate, 2003.
10. Hay RB. A rooted sense of place in cross-cultural perspective. Can Geogr 1998;42:245–66.
11. Knez I. Attachment and identity as related to a place and its perceived climate. J Environ Psychol 2005;25:207–18.
12. Christensen JH, Hewitson B, Busuioc A, et al. Regional climate projections. In: Solomon S, Qin D, Manning M, et al., eds. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S, Qin D, Manning M, et al., eds. Cambridge UK and New York: Cambridge University Press, 2007. www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf.
13. National Oceanic and Atmospheric Administration, National Ocean Service. Population trends along the coastal United States: 1980–2008. 2005. www.oceanservice.noaa.gov.
14. The H. John Heinz III Center for Science, Economics and the Environment. Human links to coastal disasters. 2002. www.heinzctr.org.
15. Webster PJ, Holland GJ, Curry JA, Chang HR. Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 2005;309:1844–6.
16. Intergovernmental Panel on Climate Change. Synthesis report. In: Pachauri RK, Reisinger A, eds. Climate change 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC, 2007. www.ipcc.ch/ipccreports/ar4-syr.htm.
17. Malilay J. Tropical cyclones. In: Noji EK, ed. The public health consequences of disasters. New York: Oxford University Press, 1997:207–27.
18. Gerrity ET, Flynn BW. Chapter 6. Mental health consequences of disasters. In: Noji EK, ed. The public health consequences of disasters. New York: Oxford University Press, 1997:101–21.
19. IOM. Damp indoor spaces and health. Washington DC: National Academies Press, 2004.
20. Toole MJ. Communicable diseases and disease control. In: Noji EK, ed. The public health consequences of disasters. New York: Oxford University Press, 1997:79–100.
21. Morbidity surveillance after Hurricane Katrina: Arkansas, Louisiana, Mississippi, and Texas, September 2005. MMWR 2006;55:727–31.
22. Anonymous. Louisiana Department of Health and Hospitals. Reports of missing and deceased. 2006. www.dhh.louisiana.gov.
23. Hunter M. Deaths of evacuees push toll to 1,577. New Orleans Times-Picayune. 2006 May 19.
24. Knabb RD, Rhome JR, Brown DP. Tropical cyclone report: Hurricane Katrina: 23–30 August 2005. National Hurricane Center, 2005. www.disastersrus.org/katrina/TCR-AL122005_Katrina.pdf.
25. National Oceanic and Atmospheric Administration (NOAA) Hurricane Katrina service assessment report. U.S. Silver Spring MD: Department of Commerce, 2006. www.weather.gov/om/assessments/pdfs/Katrina.pdf.
26. Schmidt CW. Keeping afloat: a strategy for small island nations. Environ Health Perspect 2005;113:A606–9.
27. NASA. NASA satellites measure and monitor sea level. Release: 05-175, 2005. www.nasa.gov/home/hqnews/2005/jul/HQ_05175_sea_level_monitored.html.
28. Hay J. Climate change and small island states. Tiempo 2000;36/37:1–4
29. Miller K, Yates D, Roesch C, Stewart DJ. Climate change and water resources: a primer for municipal water providers. Boulder and Denver, Colorado: American Water Works Research Foundation and the University Corporation for Atmospheric Research, 2006.
30. Scheraga JD. Opportunities to anticipate and adapt to the effects of climate change on water quality. Background paper for Water Quality Sector, National Summit on Coping with Climate Change, University of Michigan, 2007. www.snre.umich.edu/sites/webservices.itcs.umich.edu.drupal.snre/files/Water%20Quality%20Sector%20-%20Scheraga.pdf/.
31. The H. John Heinz III Center for Science, Economics and the Environment. Evaluation of erosion hazards. 2000. www.heinzctr.org.
32. Barlow PM. Ground water in freshwater–saltwater environments of the Atlantic coast. U.S. Geological Survey, Circular 1262, 2003. pubs.usgs.gov/circ/2003/circ1262/pdf/circ1262.pdf.
33. Passy C. The search for sand is no day at the beach. The New York Times 2007, Sep 16.
34. National Oceanic and Atmospheric Administration, National Ocean Service. Harmful algal blooms. oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/hab.pdf.
35. McLaughlin JB, DePaola A, Bopp CA, et al. Outbreak of Vibrio parahaemolyticus gastroenteritis associated with Alaskan oysters. N Engl J Med 2005;353:1463–70.
36. Hoegh-Guldberg O, Mumby PJ, Hooten AJ, et al. Coral reefs under rapid climate change and ocean acidification. Science 2007;318:1737–42.
37. Hughes TP, Baird AH, Bellwood DR, et al. Climate change, human impacts, and the resilience of coral reefs. Science 2003;301:929–33.
38. United Nations Environment Programme, World Conservation Monitoring Centre. In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs. Cambridge UK: UNEP-WCMC, 2006.
39. Sheppard C, Dixon DJ, Gourlay M, Sheppard A, Payet R. Coral mortality increases wave energy reaching shores protected by reef flats: examples from the Seychelles. Estuar Coast Shelf Sci 2005;64:223–34.
40. U.S. Census Bureau. Census 2000. www.census.gov/main/www/cen2000.html.
41. Tompkins E, Nicholson-Cole SA, Hurlston LA, et al. Surving climate change in small islands: a guidebook. Norwich: Tyndall Centre for Climate Change Research, University of East Anglia, 2005.
42. Albritton DL, Meira Filho LG, Cubasch U, et al. Technical summary of the Working Group 1 report. In: Houghton JT, Ding Y, Griggs DJ, et al., eds. Climate change 2001: the scientific basis. Contribution of Working Group

1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge UK: Cambridge University Press, 2001.
43. Ebi KL, Lewis ND, Corvalan C. Climate variability and change and their potential health effects in small island states: information for adaptation planning in the health sector. Environ Health Perspect 2006;114:1957–63.
44. WHO. Climate variability and change and their health effects in Pacific Island countries: Api, Samoa. Workshop report. Geneva: WHO, 2000.
45. Aron JL, Corvalán CF, Philippeaux H, eds. Climate variability and change and their health effects in the Caribbean: information for adaptation planning in the health sector. Conference proceedings, May 21–25, St. Philip, Barbados. Geneva: WHO, 2003.
46. WHO. Synthesis workshop on climate variability, climate change and health in small-island states. Workshop report. Bandos Island Resort, Maldives, December 1–4. 2003. Geneva: WHO, 2004.
47. Gertner J. The future is drying up. New York Times Magazine 2007 Oct 21.
48. Worster D. Rivers of empire: water, aridity, and the growth of the American West. New York: Oxford University Press, 1992.
49. Reisner M. Cadillac desert: the American West and its disappearing water, revised edition. New York: Penguin, 1993.
50. Pisani DJ, Rothman HK. Water, land, and law in the West: the limits of public policy, 1850–1920. Lawrence: University Press of Kansas, 1996.
51. MacDonnell LJ. From reclamation to sustainability: water, agriculture, and the environment in the American West. Boulder: University Press of Colorado, 1999.
52. Hoerling MP, Eischeid J. Climate variability and climate trends over the United States western region: which will be more relevant in the 21st century? Presentation at the 24th Summer Conference of the Natural Resources Law Center, Boulder CO, June 11–13, 2003.
53. Hjelle B, Glass GE. Outbreak of hantavirus infection in the Four Corners region of the United States in the wake of the 1997–1998 El Niño Southern Oscillation. J Inf Dis 2000;181:1569–73.
54. Knowlton K, Lynn B, Goldberg RA, et al. Projecting heat-related mortality impacts under a changing climate in the New York City region. Am J Public Health 2007;97:2028–34.
55. Riebsame WE Jr, Changnon SA, Karl TR. Drought and natural resources management in the United States. Boulder CO: Westview Press, 1991.
56. Pirie RL, de Loe RC, Kreutzwiser R. Drought planning and water allocation: an assessment of local capacity in Minnesota. J Environ Manage 2004;73:25–38.
57. Aerts J. Adaptation for river basins: connecting policy goals to the water resources system. Water Sci Technol 2005;51:121–31.
58. Meuleman AF, Cirkel G, Zwolsman GJ. When climate change is a fact! Adaptive strategies for drinking water production in a changing natural environment. Water Sci Technol 2007;56:137–44.
59. Curriero FC, Patz JA, Rose JB, Lele S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. Am J Public Health 2001;91:1194–9.
60. Gage KL, Burkot TR, Eisen RJ, Hayes EB. Climate and vectorborne diseases. Am J Prev Med 2008;35:436–50.
61. Engelthaler DM, Mosley DG, Cheek JE, et al. Climatic and environmental patterns associated with hantavirus pulmonary syndrome, Four Corners region, United States. Emerg Infect Dis 1999;5:87–94.
62. Khan AS, Khabbaz RF, Armstrong LR, et al. Hantavirus pulmonary syndrome: the first 100 cases. J Infect Dis 1996;173:1297–303.
63. Ogden NH, Maarouf A, Barker IK, et al. Climate change and the potential for range expansion of the Lyme disease vector Ixodes scapularis in Canada. Int J Parasitol 2006;36:63–70.
64. Brownstein JS, Holford TR, Fish D. A climate-based model predicts the spatial distribution of the Lyme disease vector Ixodes scapularis in the United States. Environ Health Perspect 2003;111:1152–7.
65. Ostfeld RS, Canham CD, Oggenfuss K, Winchcombe RJ, Keesing F. Climate, deer, rodents, and acorns as determinants of variation in lyme-disease risk. PLoS Biol 2006;4:e145.
66. Subak S. Effects of climate on variability in Lyme disease incidence in the northeastern United States. Am J Epidemiol 2003;157:531–8.
67. Younger M, Morrow-Almeida HR, Vindigni SM, Dannenberg AL. The built environment, climate change, and health: opportunities for co-benefits. Am J Prev Med 2008;35:517–26.
68. Wilby RL. A review of climate change impacts on the built environment. Built Environ 2007;33:31–45.
69. Ren C, Williams GM, Morawska L, Mengersen K, Tong S. Ozone modifies associations between temperature and cardiovascular mortality: analysis of the NMMAPS data. Occup Environ Med 2008;65:255–60.
70. Roaf S, Crichton D, Nicol F. Adapting buildings and cities for climate change: a 21st century survival guide. Burlington MA: Architectural Press, 2004.
71. Betsill M, Bulkeley H. Cities and climate change: urban sustainability and global environmental governance. New York: Routledge, 2003.
72. Alaska Area Native Health Service. Juneau: Alaska Bureau of Vital Statistics. 2002. www.hss.state.ak.us.
73. Rhoades ER. The health status of American Indian and Alaska Native males. Am J Public Health 2003;93:774–8.
74. Parkinson AJ, Butler JC. Potential impact of climate change on infectious diseases in the Arctic. Int J Circumpolar Health 2005;64:475–86.
75. Hennessey T. The relationship between in-home water service and the risk of infectious of the lung, skin and gastrointestinal tract among Alaska Native persons. Am J Public Health 2008. In press.
76. Parkinson AJ, Bruce MG, Zultz T. International circumpolar surveillance, an Arctic network for surveillance of infectious diseases. Emerg Infect Dis 2008;14:18–24.
77. Hoberg EP, Polley L, Jenkins EJ, Kutz SJ, Veitch AM, Elkin BT. Integrated approaches and empirical models for investigation of parasitic diseases in northern wildlife. Emerg Infect Dis 2008;14:10–7.
78. Warren JA, Berner J, Curtis T. Climate change and human health: infrastructure impacts to small remote communities in the north. Int J Circumpolar Health 2005;64:487–97.
79. Orr P, Lorencz B, Brown R, et al. An outbreak of diarrhea due to verotoxin producing Escherichia coli in Canadian Northwest Territories. Scand J Infect Dis 1994;26:675–84.
80. Kvernmo S, Heyerdahl S. Acculturation strategies and ethnic identity predictors of behavior problems in arctic minority adolescents. J Am Acad Child Adolesc Psychiatry 2003;42:57–65.
81. Sundquist J, Johansson SE. The influence of exile and repatriation on mental and physical health: a population-based study. Soc Psychiatry Psychiatr Epidemiol 1996;31:21–8.
82. McCollum AT. The trauma of moving: psychological issues for women. Newbury Park CA: Sage Publications, 1990.
83. Wood D, Halfon N, Scarlata D, Newacheck P, Nessim S. Impact of family relocation on children's growth, development, school function, and behavior. JAMA 1993;270:1334–8.
84. Thomas SL, Thomas SD. Displacement and health. Br Med Bull 2004; 69:115–27.
85. Snyder R, Williams DR, Peterson GP. Culture loss and sense of place in resource valuation: economics, anthropology, and indigenous cultures. In: Jentoft S, Minde H, Nilsen R, eds. Indigenous peoples: resource management and global rights. Delft, The Netherlands: Eburon, 2003.
86. Kirsch S. Lost worlds: environmental disaster, "culture loss", and the law. Curr Anthropol 2001;42:167–78.
87. Hughes CC, Tremblay MA, Rapoport RN, Leighton AH. People of cove and woodlot: communities from the viewpoint of social psychiatry: the Stirling County study of psychiatric disorder and sociocultural environment, vol 2. New York: Basic Books, 1960.
88. National Science and Technology Council, Committee on Environment and Natural Resources. Grand challenges for disaster reduction: a report of the Subcommittee on Disaster Reduction. 2005. www.nehrp.gov/pdf/grandchallenges.pdf.
89. Adger WN, Hughes TP, Folke C, Carpenter SR, Rockstrom J. Social-ecological resilience to coastal disasters. Science 2005;309:1036–9.
90. Vorkinn M, Riese H. Environmental concern in a local context: the significance of place attachment. Environ Behav 2001;33:249–63.
91. Uzzell D, Pol E, Badenas D. Place identification, social cohesion, and environmental sustainability. Environ Behav 2002;34:26–53.
92. Lewicka M. Ways to make people active: the role of place attachment, cultural capital, and neighborhood ties. J Environ Psychol 2005;25:381–95.
93. Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. Climate change: the public health response. Am J Public Health 2008;98:435–45.
94. Ebi KL, Semenza JC. Community-based adaptation to the health impacts of climate change. Am J Prev Med 2008;35:501–7.
95. Brouwer R, Akter S, Brander L, Haque E. Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. Risk Anal 2007;27:313–26.