Climate Change and Infectious Disease Patterns in the United States:

Public Health Preparation and Ecological Restoration as a Matter of Justice

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Abstract

There exists an ancient and delicate balance between the Earth's climate systems and human health. As the Earth's climate systems experience disruption, so will the systems of human health. With disruptions of weather patterns come increased hazard events, causing more floods, droughts, and presence of vectors. These changes ultimately cause an increase in infectious disease and new disease patterns affecting the global population. In the United States, there are several geographic areas that are at an increased risk of hazard events. More importantly, there are also populations that are distinctly more at-risk of contracting infectious disease due to underlying vulnerabilities, as indicated by social determinants of health. This document discusses infectious disease outbreaks that we can predict are coming to the United States, where we can expect to see these predictions manifest, based on our current knowledge, and what the United States, on a local level, needs to do in order to best prepare for these imminent threats. Due to the fact that portions of the population are being unjustly burdened by climate vulnerabilities and infectious disease, the timely responses to these communities is truly a matter of environmental justice. In order to best prepare for the inevitable, this paper discusses necessary partnerships that need to be made between the public health and environmental/ecology fields to form a holistic, just approach to communities on a local level.

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Introduction

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In order to best prepare for the inevitable, this paper discusses necessary partnerships that need to be made between the public health and environmental/ecology fields to form a holistic, just approach to communities on a local level.

To begin, the relationship between climate change and infectious disease will be explained, as well as introductory information of infectious diseases, which includes defining emerging and re-emerging infectious diseases. To clarify what can be expected in terms of disease burden in the United States, infectious disease is broken down into its three main categories.

The three main infectious disease categories are water-borne diseases, food-borne diseases, and vector-borne diseases. In order to gauge infectious disease risk in the United States, the most commonly found diseases in each category are discussed in greater detail.

The most common water-borne diseases are Cholera and Cryptosporidiosis. These diseases are most commonly found in areas lacking adequate public health infrastructure and abundant in unsanitary living conditions. Communities can experience significant increases in transmission of Cholera in times of disaster. For example, large flood events can threaten the integrity of the public water supply and cause damage to infrastructure such as wastewater treatment plants. When wastewater treatment plants shut down or experience damage, it becomes very likely that untreated waste will be released into the public water supply, causing widespread illness. The link between waterborne diseases and climate change is seen through the increase of severity and frequency of hazard events such as storms as well as in times of drought.

Foodborne diseases are also extremely common in times of disaster. Salmonella and Norovirus are common foodborne diseases in the United States. Foodborne diseases, caused by chemicals, parasites, chemicals, and toxins, are linked to climate change as they are similarly linked to an increase in hazard events. If adequate access to clean water and soap is not present in a community, the likelihood of foodborne diseases occurring increases, as food is handled in unsanitary conditions. Foodborne diseases such as the Norovirus are easily transmissible and run rampant in highly populated, closed environments such as camps and cruise ships.

Exposure to vector-borne diseases increases as the earth's temperatures become warmer, precipitation increases, and natural forest buffers are removed. Warmer temperatures provide longer life cycles for vectors such as ticks and mosquitoes. Increased precipitation provides stagnant pools of water which also attract mosquitoes, providing them with more suitable habitats, especially in urban areas. The removal of natural forest land also removes the protective barrier between vectors and humans, therefore increasing human exposure during the warm summer months, which is one of the main explanations for Lyme disease becoming the most common vector-borne disease in the United States.

In the next section, specific geographic areas of the U.S. that are especially vulnerable to the effects of climate change and, therefore, infectious disease, will be pinpointed. These specific vulnerabilities and their relation to increased infectious disease rates will be discussed at greater length to gain an understanding of not only what the United States can expect to see, but also where the U.S. can expect to see it.

The third section discusses climate-related health impacts as an example of ongoing environmental injustice on specific portions of the U.S. population. There are specific portions of the population that are unfairly burdened by pre-existing vulnerabilities to infectious disease, already suffering from the effects of poor environmental conditions caused by exposure to pollution. This section further discusses these portions of the population in order to highlight the environmental injustice so that it can be corrected.

The final section discusses what actions the United States needs to take in order to prepare for the imminent threat of climate-related infectious diseases and prepare communities to deal with the associated public health impacts. Ecological restoration is presented as the most cost-effective, efficient, and effective method of preparation and adaptation for communities to utilize in order to mitigate the effects of hazard events. It is also presented as necessary in order to restore environmental justice to those who have been unfairly burdened. This section discusses the approaches that need to be made in the public health and environmental sectors, but also the partnership that must form between these two fields in order to best serve mankind, providing a holistic approach to the issue.

The sections of this thesis have been specifically chosen to clarify the importance of the relationship between climate change and infectious disease in the United States. This has been done through the analysis of infectious disease history and specific examples in the United States and where we can see infectious disease outbreak, as predicted by climate change data.

While this is a useful endeavor in and of itself, this thesis further serves to illuminate the importance of ecological restoration and public health preparation to best prepare communities of the United States to prepare for these imminent threats. As the time for completely reversing the damage humans have caused to the earth as passed, it is now important to shift our collective focus to adaptation, preparation, and mitigation of the inevitable.

Introduction to Climate Change and Human Health

There is a delicate balance between the Earth's climate systems and human health. When one of these climate systems is disrupted, the state of human health is negatively impacted. Disruption has multiple impacts. Heat-related illnesses, for example, increase with rising temperatures. Coinciding with higher average temperatures are increased heat-related deaths. This phenomenon is explained through basic human thermoregulation and the microcosm of the human body, also itself a delicate system. As the temperature of the human body increases past 38˚, heat exhaustion begins to set in, physical and cognitive functions become severely impaired, there is a risk of damage to organs, and risk of mortality increases exponentially (Smith 2008).

Poorer air quality, exacerbated by higher temperatures, increases the incidence of respiratory illnesses such as asthma. Increased average temperatures and precipitation rates also create ideal environments for vectors, increasing the potential for vector-borne infectious diseases.

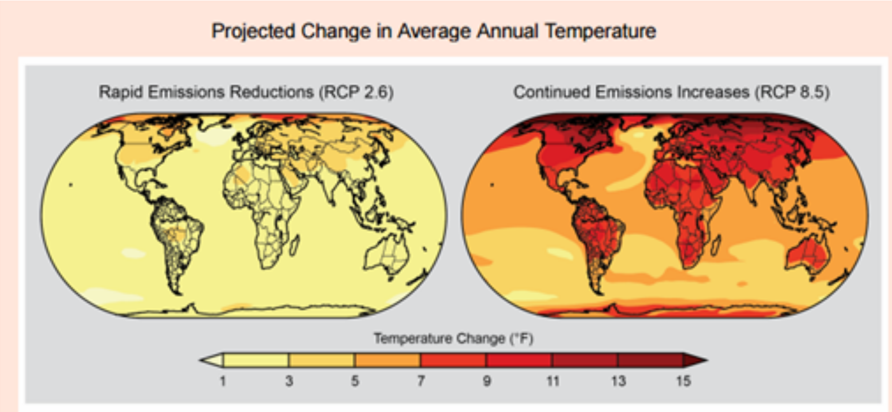


Figure 2.5. Projected change in average annual temperature over the period 2071-2099 (compared to the period 1970-1999) under a low scenario that assumes rapid reductions in emissions and concentrations of heat-trapping gases (RCP 2.6), and a higher scenario that assumes continued increases in emissions (RCP 8.5). (Figure source: NOAA NCDC / CICS-NC).

As the figure demonstrates, increased average annual temperature will continue to increase significantly through 2099 without a significant decrease in emissions. With this disturbance in annual temperature, climate-related illness and infectious disease are likely to become just as increasingly apparent.

Climate change refers to the alterations in regional and global climate patterns, such as average temperatures or annual precipitation. These changes result in the long-term increase of the Earth's average recorded temperatures, known as global warming. The average temperatures of the Earth are increasing as a result of anthropogenic causes; the over-consumption of fossil fuels released into the Earth's atmosphere. These air pollutants, such as carbon dioxide, enter the earth's atmosphere and remain there, trapping heat inside of earth's atmosphere, creating a hotter planet. The presence of these pollutants in the air, coupled with the greenhouse gas effect causes a multitude of changes within the Earth's complex systems.

Climate change causes new weather patterns resulting in storms of increased intensity and frequency with surges and droughts, ocean acidification, ice melt, sea level rise, erosion, and as mentioned, a hotter planet, affecting all manner of life on Earth.

Of course, mankind has contributed to the over-use of the Earth and depletion and degradation of its natural resources, and the karmic debt from its destruction and our role and implication in it will return to plague us; literally, presenting as emerging and re-emerging strains of infectious diseases.

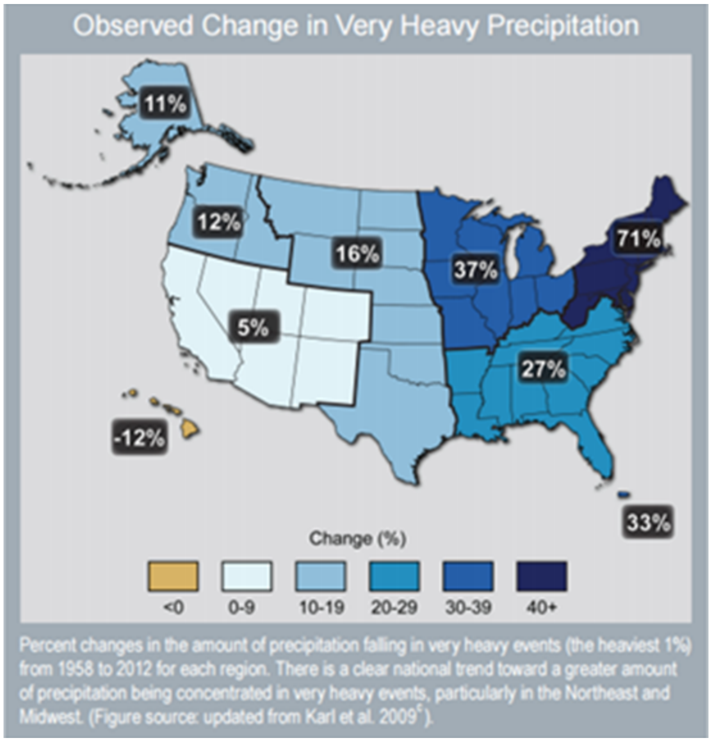
While no one is immune to the effects of climate-related public health impacts, the disease burden is disproportionately placed on vulnerable populations, creating an issue of environmental and public health justice that must be addressed.

The relationship between climate change and infectious disease is by no means a new phenomenon. In 1967 the United States Surgeon General, William Stewart, famously announced that Americans would soon be able to “close the book” on infectious disease. Accumulating infectious disease research and data have proven him wildly incorrect, as decades later 1/3 of the world’s population still dies from infectious diseases, with no end in sight (Walters 2003:1).

Though the relationship is ancient, there are aspects of this issue that are new. The human race is at a current rate of consumption and existence that is completely unprecedented, leading to a change in atmospheric conditions and a global disease burden that is also unprecedented. We are experiencing new strains of infectious disease, emerging infectious disease, re-emerging infectious diseases, and more virulent and antibiotic-resistant strains of diseases. There is also clearer data on the fact that specific portions of the population are unfairly burdened by vulnerability to climate-related illnesses. The age-old approach of treating the sick and suffering after the fact is no longer sufficient and requires a new approach.

It is now clear that an ecological approach to improving public health conditions is the necessary prescription. Restoring natural barriers and buffers that have been removed from the land will help prevent and mitigate the negative public health consequences of climate-related hazard events.

Climate change has an impact on the Earth's temperatures, sea levels, weather patterns, biodiversity, and the health of both animal and humans. As temperatures become more severe, areas of the planet will face increasingly disruptive weather patterns and weather-related events; homelands becoming inhospitable and, further still, ill-suited to human life. Entire populations will experience scarcities of natural resources due to biodiversity loss and rampant infectious disease transmission, forcing them to relocate and find homes elsewhere. It is entirely possible climate change will necessitate entire countries becoming climate refugees (Lovelock 2009:17).



Percent changes in the amount of precipitation falling in very heavy events (the heaviest 1%) from 1958 to 2012 for each region. There is a clear national trend toward a greater amount of precipitation being concentrated in very heavy events, particularly in the Northeast and Midwest. (Figure source: updated from Karl et al. 2009[6]).

This increase in precipitation spread across the United States will not only cause increased conditions for hazard events such as flooding, but also prime conditions for infectious waterborne disease outbreaks.

In order to address future increases in infectious disease outbreaks, it is important to look at the history of these diseases. An analysis of historical patterns of disease history will allow us to target emerging threats for the future and, therefore, prepare for them. It is only through preparation that we can protect our communities effectively and efficiently.

Throughout history there have been several “waves” of epidemics and infectious diseases known to mankind. Historians such as W. H. Mcneill have attributed the first wave of epidemics, occurring 10,000 years ago, to the beginnings of human and agricultural settlements, increasing human contact with cattle and livestock, allowing humans to come into contact with microbes manifesting in smallpox, measles, and leprosy (Walters 2003:6).

The second wave of epidemics, occurring 2,500 years ago, coincides with increased human contact with central systems of civilization, increasing the exposure of humans to pathogens. The third wave of epidemics coincides with the rampant increase of global exploration, pushing humans closer to new microbes and pathogens, and therefore, disease (Walters 2003:6).

With the continuous over-development of the Earth, disrupting the natural ecology, the effects of climate change, and the present state of overwhelming and unprecedented human contact through modern conveniences such as global travel and commerce, it should come as no surprise that humans are essentially entering into a fourth wave of epidemics (Walters 2003:6). A wave we have brought upon ourselves with zero preparation for its consequences.

There are several ways in which climate change negatively interacts with public health. Climate change brings with it changes in temperature and weather, thus impacting air quality and living conditions. Increased temperatures cause a myriad of health issues such as stroke as well as increasing complications of chronic respiratory illnesses such as asthma. Additionally, climate change and increasing emergence, frequency, and virulence of infectious disease are directly correlated. In 2015 and 2016, the United States population, alone, has been introduced to emerging infectious diseases (EID) such as Ebola and Zika Virus. These diseases are part of a global pattern of increasing EIDs; increasing at a rate of 5 emergent events per year and, according to USAID, this is only the beginning (USAID Predict 114).

Emerging infectious diseases, EIDs, are primary infections which seem to have recently appeared in the human population or are occurring with a rapidly increasing rate across geographic regions (DeSalle 1999:53, Jones, Patel, and Levy 2008:1). Begun by introducing the infection into a new population, EIDs are then continued by the infection rate of transmission (DeSalle 1999:53). The emergence of infectious disease is facilitated by globalization, agricultural and land development, and changes in human behavior.

Infectious disease is delicately intertwined with human behavior. Disease transmission relies on increased human interaction in populations, especially in densely populated areas such as urban cities. This is further compounded through the facilitation of modern advancements in transportation, such as travel by air. Diseases can be spread from small communities to larger cities through population movements such as forced migration or any type of travel or mass-transit system (DeSalle 1999:53-54).

The risk of disease emergence and exposure to these diseases is directly tied to the frequency in which a population comes into contact with certain pathogens. These pathogens are then given a greater chance of environmental survival through factors of temperature and relative humidity (USAID Predict 109). As indicated by the figures included above, the annual temperature and rates of precipitation in the United States are projected to increase rapidly, meeting the requirements of both of these factors, increasing the possibilities of infectious disease transmission.

The United States is also vulnerable to re-emerging infectious diseases. Re-emerging infectious diseases, generally well-documented and recognized threats, occur when the public health infrastructure previously in place, such as vaccinations, water purification systems, and vector control, have lapsed or collapsed altogether. Without vigilant surveillance of the safeguards in place to prevent outbreaks, infectious diseases are very likely to re-emerge. This occurrence is frequently found in developing countries suffering from a lack of adequate medical care, but is also found in dense, urban inner cities of the industrialized world (DeSalle 1999:56).

Living in a densely populated city is only one way to increase possible exposure to infectious diseases. There are several ways in which human contact with disease is increased: trade, travel, misuse of insecticide resulting in species resistance, population growth and overcrowding leading to poor sanitation and living conditions, antibiotic resistance of pathogens, and, not least of all, agricultural and land development, as both directly interfere with natural biodiversity (DeSalle 1999:61).

When the biodiversity of an area is negatively impacted by increased use or removal of flora and fauna, the entire ecosystem is disrupted and can lead to increased infectious disease patterns. This is largely caused by the irritation of a species or vector, whose target population will move from a former naturally controlled buffer of dense forests to the increasing human population entering into the area. This is problematic as the best way to reduce exposure to disease is by reducing human exposure to the zoonotic source of a disease.

As will be discussed later, this is the largest contributing factor of Lyme disease becoming the top vector-borne infectious disease in the United States.

Additionally worrisome is that, according to the United States Agency for International Development (USAID), the state of American development, travel, and trade has consistently kept the United States as one of the top twelve countries most at-risk of importing infectious disease.

Section I: Infectious Diseases

The disruption of climate systems causes strain and disruption of current infrastructure in the United States, in turn causing disruptions in public health, especially infectious disease. To clarify, climate disruptions place a burden on health infrastructure that is not prepared to address emerging strains of infectious diseases, increased patterns and rates of exposure, increased rates of transmission and infection, and increased vulnerabilities in various populations. Therefore, it is the intention of this study to assist public health officials assess, predict, and anticipate disease pathways and impacts.

The three main categories of illnesses encompassed by the term “infectious disease” are waterborne diseases, food-borne diseases, and vector-borne, or zoonotic, diseases. Climate change affects each of these individual categories, disrupting the natural ecology of a region, causing an increase in infectious disease patterns.

Waterborne Illnesses

Waterborne illnesses, a pressing category of infectious disease, are caused by a variety of microorganisms, contaminants, and toxins present in the water supply. Climate change alters the natural ecology of oceans and coastal ecosystems. These disruptions are lead to alterations in the pH level of water, nutrient levels, salinity measurements, contaminant runoff, and can also cause a scarcity of water (WHO 2015).

Climatic changes such as increased rates of precipitation can often cause flooding of sewers and water treatment plants, leading to a breakdown of mechanical functioning, and subsequent vulnerability of the water supply (Guzman-Herrador 2015).
Just as influential are droughts, which, due to a lack of water and high concentration of waste leads to an increase in available effluent pathogens to also cause malfunctions of waste treatment facilities, releasing contaminants into surface water (WHO 2015).

Droughts also produce water insecurity and prompt individuals to store their own, creating ideal habitats for vectors carrying harmful bacteria (Guzman-Herrador 2015). The most common types of waterborne illnesses are cholera and cryptosporidiosis, among other gastrointestinal diseases.

Cholera, migrating in the 19th century from its original reservoir in the Ganges River delta in India, is currently in its seventh pandemic, having killed millions of people across all continents. There are approximately 1.4-4.3 million cases of cholera annually and it is recorded that, of these annual cases, 28,000-142,000 end in death (WHO 2015).

Now considered to be endemic, or regularly found, in many countries, cholera is an acute diarrheal disease caused by the ingestion of an element contaminated with bacterium known as *Vibrio cholorae*. There are two serogroups of *V. cholorae* that cause outbreaks of cholera, *V. cholorae* 01, which causes the most outbreaks, and *V. cholorae* 0139 (WHO 2015). Cholera is extremely virulent, compounded by its short incubation period of 2 hours to 5 days (National Institute of Environmental Health Sciences 2014, WHO 2015).

Affecting both children and adults, if left untreated, cholera can be fatal very quickly. Bacteria from cholera can remain in feces anywhere from 1-10 days after infection and, therefore, these pathogens are transported very easily back into the environment, readily infecting more of the population.

Cholera is directly linked to poor environmental conditions and inadequate management of these conditions. Typically, cases of cholera are found to be more prevalent in geographical locations known as peri-urban environments, which are areas located on the direct outskirts of cities. In these areas basic public health and sanitation infrastructure is not present or adequate, therefore increasing the poor environmental conditions linked to cholera transmission.

Additionally, camps and settlements of refugee populations are areas in which cases and transmission of cholera are seemingly interminable. Always overpopulated, refugee camps force close contact and cohabitation of people in areas lacking sufficient potable water, public health access and basic sanitary requirements, creating a perfect environment for outbreaks of cholera.

The other most common waterborne disease is Cryptosporidiosis. The peaks of Cryptosporidiosis occurrence in North America are late summer and early fall. This waterborne illness is associated with both increased rainfall, especially in warmer climates, as well as prolonged dry periods, such as droughts, in which a high amount of the pathogen can be concentrated in surface and groundwater sources (CDC 2015).

Cryptosporidiosis is a diarrheal disease caused by cryptosporidium parasites found in human and/or animal hosts. The disease is transmitted to other animals and humans through infected feces (CDC 2015). Most commonly, Cryptosporidiosis is quickly transmitted through infected sewage contaminating drinking water and recreational waters such as swimming pools, fountains, hot tubs, jacuzzis, rivers, lakes, ponds, streams, and springs.

Cryptosporidiosis can also be transmitted through food that came into contact with infected feces and sexual contact with infected feces (CDC 2015).

The portions of the population most at-risk of Cryptosporidiosis are children in daycare and childcare workers, international travelers, backpackers, hikers, and campers drinking or coming into contact with unfiltered and untreated water, water from shallow and unprotected wells, anyone working with infected cattle, and any caregivers of those affected. Individuals at-risk of becoming seriously ill are those with compromised immune systems, young children, the elderly, and pregnant women.

This waterborne infectious disease is important to note as it has already caused the largest waterborne infectious disease outbreak in United States history. In 1993 over 400,000 people fell ill with Cryptosporidiosis in Milwaukee after coming into contact with the public water supply (CDC 1993). As it has already posed a significant threat in an area, it is important to monitor as increasing hazard events increase the likelihood of additional outbreaks.

The majority of the United States affords its residents with these basic standards of living, however, with the influx of extreme weather events, refugees, and conditions forcing population migrations within the U.S., it is very likely that cases of cholera will increase in coming years. Additionally, Cryptosporidiosis has already caused the largest waterborne illness in the United States, displaying its potential impacts on public health as we move forward. As it is likely to occur in both periods of heavy rainfall and flooding as well as periods of drought, the likelihood of its prevalence due to climate change-related impacts is increased exponentially.

New Orleans, Louisiana Post-Katrina

The United States can expect to see exposure to infectious water-borne diseases increase. As the frequency and severity of storms increase, we can expect to see significant damage to already vulnerable coastline populations. In severe storm situations, disruptions are likely to cause increased occurrence and transmission of infectious diseases. The likelihood of these outcomes is evident through the analysis of past hazard events, such as Hurricane Katrina, which caused disaster in New Orleans, Louisiana in 2005.

On August 29, 2005 Hurricane Katrina began to decimate New Orleans, Louisiana’s infrastructure with winds over 60 miles per hour. Approximately ⅘ of New Orleans’ population was lost, not only due to deaths, but relocation to neighboring states of Mississippi, Arkansas, and Texas. The destruction of Hurricane Katrina created the largest population displacement in United States history, necessitating the mass movement and relocation of a large population, such as the 150,000 individuals who sought refuge in stadiums, convention centers, apartments, hotels, and churches in Houston, Texas.

While a large number of the population was able to evacuate the area, the official evacuation order released on August 28th by Mayor Ray Nagin, not all New Orleans residents had this ability. 100,000 people were unable to evacuate, mostly due to the lack of transportation, such as ownership of a vehicle, or lack of guaranteed shelter in another location. Research performed on the association between race/ethnicity and evacuation patterns only serve to validate what occurred in New Orleans; many of the 100,000 residents who did not evacuate the area were the among the city's poorest and most economically disadvantaged residents, a large percentage of these residents were African American (Byrnes 2013). Whether these individuals did not have adequate means of transport out of the city, either because of the lack of a connected social network outside of the city to ensure them shelter, or because they had a responsibility of taking care of an elderly or ill family member, many of these individuals were left unprepared and unable to face the destruction of the storm.

Even those who were lucky enough to be transported to shelter in the Superdome, the New Orleans sports and exhibition stadium/arena, were left to face inadequate conditions in a heavily populated, unsanitary, and unsafe environment. News reports and personal recollections of the conditions at the New Orleans Superdome horrified the nation. Reports of unconfirmed rapes, violence, and suicides as well as a lack of resources such as blankets, food, medication, and water plagued the inhabitants of the Superdome. Additionally, there was no air conditioning in the facility, leading to dangerously high temperatures, little to no circulation of air, overflowing toilets, trash and waste build-up in the living quarters, and a lack of access to not only potable water, but to water, in general.

On Wednesday, September 7th, a week from Katrina's initial contact, 5 individuals, evacuated to Texas and Mississippi, were confirmed dead as a result of a generally benign strain of Cholera (CNN 2005). Public health workers of the disaster relief were extremely concerned about the levels of toxic chemicals present in the water, but also e.coli as a result of a breakdown in the area's sewage and waste disposal system (CNN 2005).

This type of condition is exactly the kind of environment in which we will see rampant transmission of infectious disease, especially waterborne diseases. Additionally, the 120,000 FEMA trailers that were provided to those displaced proved to be toxic with harmful levels of formaldehyde, a known carcinogen, further threatening human health. Without the adequate infrastructure, the United States can expect to see more Superdome-esque situations to occur, creating the threat of both environmental and public health injustice, as the socioeconomically disadvantaged populations are always more at-risk.

While 80% of cholera cases are treatable with re-hydration salts, larger scale interventions need to be developed and put in place in order to prevent cholera, cryptosporidiosis and other infectious disease outbreaks altogether (WHO 2015).

In order to initiate this, there need to be interventions in order to target unsanitary environmental and living conditions in times of disaster. The development and maintenance of piped water systems with the use of chlorination on a larger scale, interventions on the household level of disinfection of water supplies, safe water storage containers in times of drought and scarcity, and construction of waste disposal systems in areas currently lacking them or in need of updated systems are all necessary interventions to bolster public health resiliency in times of systemic disaster and infrastructural breakdown (NIEHS 2013).

Food-Borne Illnesses

Food-borne illnesses are caused by microbes such as bacteria, parasites, chemicals, and toxins, often transmitted through consumption of unsafe and contaminated food and water. The presence of these foodborne disease agents is exacerbated by extreme weather events and increased temperatures, increasing their distribution and, often, virulence. The World Health Organization estimates that approximately 600 million people experience illness after consuming contaminated food every year (WHO 2013). 400,000 individuals experience fatal complications due to these illnesses, annually. Analysis of these statistics prove a disease burden expressed through the loss of approximately 33 million health years. These years are expressed in Disability Adjusted Life Years, or DALYS, which are the number of years lost due to illness, disability, or premature deaths of individuals (WHO 2013).

There are more than 200 diseases caused by unsafe and contaminated food, ranging from episodes of diarrhea to cancer (WHO 2013). One of the main bacterial food-borne illness in the United States is Salmonella.

Salmonella, salmonellosis, causes approximately one million foodborne illnesses in the United States each year. Of these illnesses, there are 19,000 hospitalizations and 380 deaths (CDC 2016). Salmonella is a bacterial infection that affects the intestinal tract and resides in the intestines of animals and humans, shed through feces.

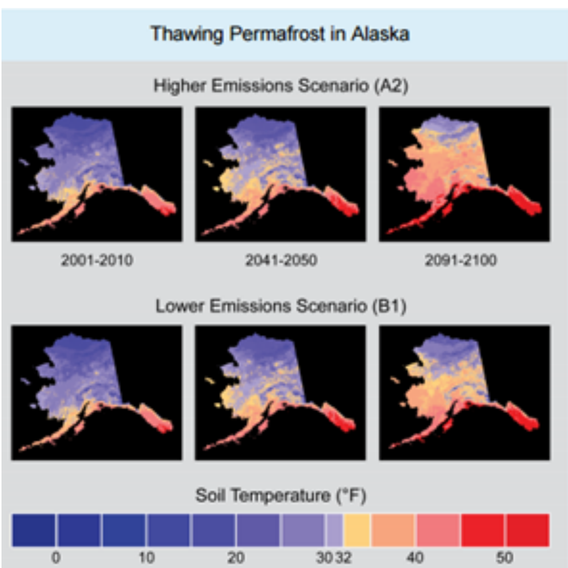
Unfortunately, Salmonella is a very common and virulent bacteria, possessing the ability to survive for several weeks in a dry environment and several months in water. Salmonella in humans is often contracted through exposure to contaminated food or water. The public health field has been tracking salmonella infections in the United States since 1962, having identified over 2,500 different strains of the bacteria. Symptoms of salmonellosis include a fever, headache, nausea, vomiting, abdominal pain, and diarrhea usually lasting 4-7 days (CDC 2016).

The Norovirus is a foodborne illness causing acute gastroenteritis, which is the inflammation of the stomach and intestines. Highly infectious, the virus presents with symptoms of abdominal pain, diarrhea, and vomiting, and can be transmitted through contact with infected individuals, contaminated food and water, and contact with contaminated surfaces. The Norovirus is the most common cause of foodborne disease outbreaks in the United States, having caused 48% of them between 2009 and 2012 (CDC 2013).

The virus causes 19-21 million illnesses and 570-800 deaths, annually and is spread most quickly in highly populated, closed off settings such as schools, nursing homes, and refugee camps (WHO 2013).

The data currently available regarding foodborne diseases is limited as The WHO's 2015 published report on the global disease burden of 31 foodborne disease agents was the first of its kind and underreporting is rampant in this area. It is clear, however, that foodborne illnesses are compounded by unsanitary conditions as exposure to bacteria inevitably increases. Without clean water, access to soap, and the availability of food storage options, foodborne illnesses can be transmitted very quickly in closed environments, creating a public health dilemma.

Arctic Indigenous Communities



igure 12.6. The maps show projected ground temperature at a depth of 3.3 feet assuming ontinued increases in emissions (A2 scenario) and assuming a substantial reduction emissions (B1 scenario). Blue shades represent areas below freezing at a depth of .3 feet and yellow and red shades represent areas above freezing at that depth (see h. 22: Alaska for more details). Many Alaska Natives depend on permafrost for ice ellars to store frozen food, and replacing these cellars with electricity-driven freezers expensive or otherwise infeasible. Permafrost thawing also affects infrastructure like ads and utility lines. (Figure source: Permafrost Lab, Geophysical Institute, University Alaska Fairbanks).

This figure depicts the thawing of the permafrost in the Arctic which, as indicated, is only going to continue as soil temperatures continue to increase. Even if lower emissions begin now, there will still be considerable irreversible damage, threatening Indigenous communities in the Arctic.

Indigenous communities in the Arctic are already experiencing difficulties adapting to a changing climate. Melting sea ice, thawing permafrost (permanently frozen soil), increased unpredictability of weather patterns, and a reduction of fish populations have severely disrupted Indigenous communities. The sharp thawing of permafrost has caused serious erosion and flooding resulting in the damage and/or loss of infrastructure such as roads, buildings, and homes. Due to the compounding effects of climate change, over 30 Native villages in Alaska are either still in need of, or are in the process of entirely relocating (National Climate Assessment 2016, USGCRP 2016).

These changes in the earth's systems have caused a disruption of systems of not only the land, but also traditional ways of living. Traditional practices of hunting and subsistence living are being disrupted, affecting every aspect of Indigenous life. Rising temperatures and a decrease in available water for farming have caused Indigenous communities, such as the Navajo, to suffer from decreased crop yields. The cultural practices of these communities are embedded knowledge, having been passed on for generations. A disruption of this embedded knowledge causes a need to deviate from the consumption of traditional foods, altering nutrition, often leading to increased obesity and diabetes.

These underlying health conditions prime the human body to be more at-risk of infectious disease as the human body's natural functioning and immunity become compromised (National Climate Assessment 2016, USGCRP 2016).

It is also well documented that the forcing of ethnic populations to abandon traditional homelands and/or their traditional diets has inevitably led to increases in chronic illnesses such as diabetes, heart disease, cancer, and various allergies (Nabhan 2004:86).

Also, as previously mentioned, effects of climate change exacerbate the presence and virulence of foodborne disease agents in an environment and a population, but it has other effects such as the melting of the permafrost in the Arctic.

The melting of permafrost in the Arctic certainly has negative environmental consequences, but it also negatively affects the Native populations who have utilized the permafrost as a natural refrigeration and storage system for their food supply. The traditional Inupiat community located in the North Slope region of Alaska on the Colville River is an example of this. The Inupiat natural ice cellars are cut directly into the permafrost and are used to store their supplies of caribou and seal meat. The increasing temperatures in the Arctic region have caused the melting of the permafrost and, thus, the spoilage of stored meat, resulting in increased risk of bacterial foodborne diseases (World Health Organization 2016).

Vector-borne Diseases

With an increasing amount of atmospheric changes due to climate change, such as increasing levels of precipitation and higher annual temperatures, come an increase, for example, of stagnant pools of water and poor drainage which provide more suitable habitats and breeding areas for vectors carrying diseases, such as mosquitoes. This pattern is consistent with increases in mosquito-borne infectious diseases such as malaria from many parts of the world. Analyzing vector-borne disease patterns in the United States gives us a unique opportunity to see specific examples of re-emerging infectious diseases such as Malaria, evidence of surges in endemic vector-borne disease such as the West Nile Virus and Lyme disease, and also emerging infectious diseases such as the Zika virus.

As climate change alters atmospheric conditions and the degradation of forests continue, the increase in mosquito populations are fostered (Mark Walters 2003:3). Vector borne diseases are transmitted between blood-sucking arthropod vectors and vertebrate hosts (DeSalle 1999:61), which is cause for concern because approximately 75% of human diseases are actually carried by wild and domestic animals (Walters 2003:1).

In a study conducted by the United States Agency for International Development, wildlife species that are most closely related to human beings are most likely to present the highest risk for EIDs.

Bats, rodents, and primates share the greatest amount of viruses with humans and are, therefore, the most likely to carry a virus which emerges in humans (USAID Predict 2016:1). This is consistent with our current knowledge of the rodent-associated Bubonic Plague of Europe in the 1300s, more popularly known as the Black Death, which annihilated 1/3 of the population (Walters 2003:1).

Malaria is a vector-borne, acute febrile illness transmitted through the bite of an infected female *Anopheles* mosquito which threatens about 3.2 billion people, globally (CDC 2016). Malaria is caused by *Plasmodium* parasites which was officially discovered in 1880 by a French army surgeon stationed in Constantine, Algeria. Currently, five species of *Plasmodium* parasites are known to cause Malaria in humans, the two most prevalent being *Plasmodium falciparum (P. falciparum)* and *Plasmodium vivax (P. vivax)* (CDC 2016, DeSalle 1999:62). *P. falciparum* is the most prevalent malaria parasite on the African continent and is the cause of most malaria-related deaths, globally. *P. vivax,* on the other hand, is the dominant Malaria parasite in countries outside of Sub-Saharan Africa. If an individual is bitten by an infected female *Anopheles* mosquito, the symptoms of Malaria will manifest approximately 7-15 days post-bite.

Malaria manifests in symptoms such as fever, headache, chills, vomiting, anemia, and jaundice and, in severe cases, multi-organ involvement is also very possible (CDC 2016, DeSalle 1999:62). As to be expected with most infectious diseases, those most at-risk for contracting

Malaria are infants, children under five years of age, pregnant women, the elderly, the chronically ill, non-immune migrants, travelers, and mobile populations (CDC 2016).

Having been officially declared eliminated from the United States in 1951, there are approximately 1,500-2,000 cases of Malaria diagnosed in the U.S. each year, most of these cases occurring in those recently having travelled abroad. However, while local outbreaks of Malaria in the U.S. are rare, they do still occur.

To illustrate, between the years 1957 and 2015, 63 outbreaks of locally transmitted mosquito-borne Malaria were reported and between 1963 and 2015 there were 97 cases of transfusion-transmitted Malaria in the United States (CDC 2016).

Locally transmitted mosquito-borne Malaria occurs when a local mosquito bites a person carrying Malaria parasites, acquired from an area in which Malaria is endemic. This now infected mosquito then bites a local individual, transferring the acquired Malaria parasites to this individual, transmitting the illness, locally.

Malaria is also transmitted through a phenomenon known as “Airport Malaria”. “Airport Malaria” is caused by infected mosquitos that are transported via aircraft from a Malaria-endemic country to a non-endemic country where the infected mosquitos can bite local residents, transmitting Malaria to those who have not recently travelled abroad (CDC 2016). Rarer still are events of congenital Malaria and transfusion-transmitted Malaria. Congenital Malaria occurs when an infected mother transmits parasites to their offspring before or during pregnancy and before or during delivery.

Transfusion-transmitted Malaria occurs in the United States approximately every two years, causing a potentially severe and fatal complication in blood recipients. There are no approved or available tests in the United States to test donated blood for Malaria, recipients must rely on the careful questioning of the prospective blood donors to adhere to the guidelines in blood donation if an individual has traveled abroad (CDC 2016).

Though the United States declared Malaria eliminated in 1951, Malaria is a constant threat in terms of re-emerging infectious disease. Prior to elimination in the U.S., the three species of *Anopheles* mosquitoes that caused Malaria were the *Anopheles quadrimaculatas* in the east, *Anopheles freeborni* in the west, and the *Anopheles pseudopunctipennis* located along the border of the United States and Mexico. These three species are still prevalent in the United States which is a cause for concern of re-emergence of Malaria.

This concern has, in recent years, been exacerbated by factors such as increased insecticide resistance in mosquitos, anti-malarial drug resistant *Plasmodium* parasites, mass movement and upheaval of populations, climate changes, destruction of natural environmental buffers, large scale irrigation projects, weak public health policies, and poor economic support. A culmination of these factors means that Malaria is a constant re-emerging infectious disease threat in the United States and a genuine cause for concern (DeSalle 1999:62).

A particular area of public health concern is that areas in which Malaria is not endemic are not practiced in spotting the symptoms of Malaria, as it is no longer routine. This lack of training and knowledge increases the time it takes to diagnose an individual properly and offer treatment, which increases the likelihood of Malaria-related deaths (CDC 2016).

While the United States seems far removed from exotic-sounding infectious diseases, the increase of vectors and the increase of their contact with the human population, and thus exposure, will inevitably create a rise in re-emerging infectious disease.

The likelihood of this occurrence is further illustrated through the surge in cases of endemic vector-borne diseases in the United States. The West Nile Virus (WNV), for example, is the leading mosquito-borne disease in the United States, causing a reported 39,557 cases of West Nile Virus in the U.S. between 1993 and 2013 (The U.S. Global Change Research Program 2016). The underreporting from this virus is fairly consistent as 70-80% of those infected do not present as symptomatic. The real estimate between 1999 and 2010 is closer to 3 million people being infected (The U.S. Global Change Research Program 2016).

First occurring in the United States in New York City in 1999, it only took the WNV until 2004 to be reported throughout the contiguous U.S., one of the reasons why it has become the leading mosquito-borne disease. While 70-80% of people do not present as symptomatic, 20-30% of those infected show symptoms of an acute systemic febrile illness; presenting with headaches, muscle pain (myalgia), a rash, and gastrointestinal discomfort and distress (The U.S. Global Change Research Program 2016).

There are those who can develop severe symptoms, known as West Nile Neuroinvasive Virus, and present with: myelitis (inflammation of the spinal cord), encephalitis (inflammation of the brain), and meningitis (inflammation around the brain and spinal cord) (The U.S. Global Change Research Program 2016). Though less than 1% of those infected develop these conditions, it is possible that, with increased virulence of WNV in vector hosts, we could see an increase occur.

The process of human contraction of WNV is very interesting. Birds are actually the natural hosts of WNV. While more than 300 bird species in the United States have been implicated in the transmission of WNV, the three key bird species carrying the virus are American robins, house finches, and house sparrows. 65 mosquito species have been detected to carry the WNV, but only three C*ulex* mosquito species, *Culex tarsalis, Culex pipiens,* and *Culex quinine fasciatus* have been detected in human infection (USGCRP 2016).

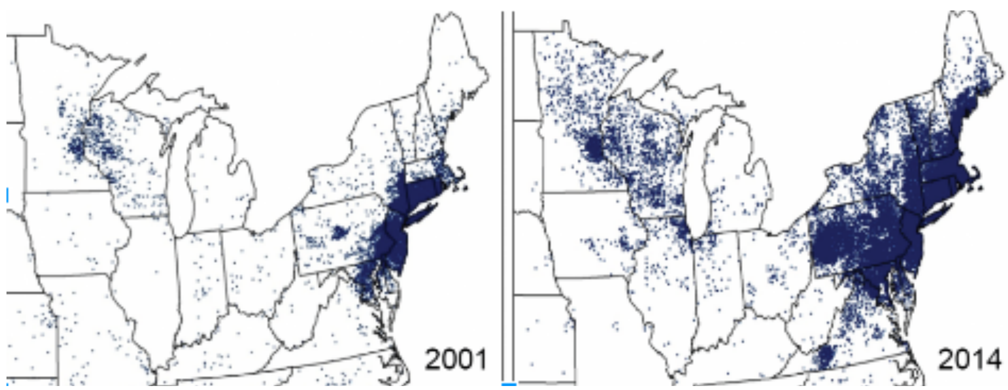
In order for a human to be infected with WNV, they have to be bitten by a mosquito that has previously bitten an infected bird. Unlike Malaria, humans are not currently capable to transmit the virus to an uninfected biting mosquito as there is too little concentration of the WNV in a human's bloodstream. This is why transmission rates of WNV through blood transfusions or organ transplants are exceptionally rare.

Climate has an extreme impact on WNV, especially given the vectors and hosts involved. Mosquitos begin passing the virus from bird to bird beginning in late Winter, early Spring with peak transmission occurring between the months of June and September (USGCRP 2016).

Projected increases in annual temperature will change migration patterns of birds and allow for the increased survival of fledglings, increasing the amount of exposure along bird migratory routes (WHO 2011). Projected increases in annual precipitation will increase the presence of mosquitos, providing a suitable habitat.

With increased presence of both birds and mosquitos coinciding with the months of the year humans in the U.S. are most likely to participate in outdoor recreational activity, predicting further increases in WNV is just common sense.

Perhaps a more accessible example for the American public is the threat of Lyme disease. Lyme disease is the number one emerging vector-borne disease in the United States with more than 300,000 cases reported annually (CDC 2011, DeSalle 1999:62, Walters 2003:3).



This image shows the increase of Lyme disease cases reported between 2001 and 2014 in only two geographic areas where Lyme disease is most common, the Northeast and the Upper Midwest. As depicted in the image, both the distribution and number of cases reported have increased monumentally within a 13 year period (CDC 2015, U.S. Global Change Research Program 2016).

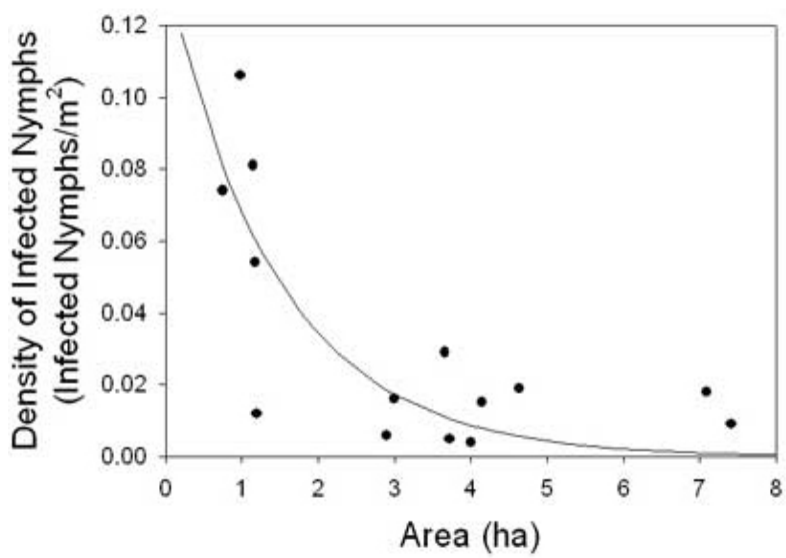
Lyme disease is an infection caused by bacteria known as a spirochete, carried by deer ticks. In the early 1970s in Lyme, Connecticut several children were diagnosed with rheumatoid arthritis, their symptoms beginning in the summer after coming into frequent contact with forested areas, which happens to be the height of tick season (NIAID 2015). It was not until 1981 that National Institute of Allergy and Infectious Disease scientist Willy Burgdorfer and colleague Alan Barbour, MD, established a connection between Lyme Disease and EM, erythema migrans, a well-known European skin rash; both caused by a spirochete, which was named *Borrelia burgdorferi sensu stricto* (U.S. Global Change Research Program 2016; NIAID 2015).

A tick carrying *Borrelia burgdorferi* transmits this bacteria, a spirochete, through its bite, generally within 36-48 hours of attachment to its host (NIAID 2015). The signature first symptom of Lyme disease is a skin rash known as erythema migrans, which is a rash presenting similar to a bull's eye pattern located at the site of the tick bite anywhere between 7-14 days post-tick bite. A multisystem inflammatory disease, Lyme disease presents with other symptoms including fever, fatigue, stiff neck, arthritis, generalized aches and pains, inflammation of the eye, nervous system complications resulting in cognitive impairments, and heart complications. Left untreated, Lyme disease can lead to more persistent symptoms, known as Chronic Lyme disease which has lifelong symptoms and debilitations (CDC 2015).

Between its initial discovery in the early 1970s, with approximately 400 cases being reported in the early 1980s, and 1992, Lyme disease became the highest reported vector-borne disease in the United States and, as aforementioned, is reported in more than 300,000 cases annually (CDC 2011 and DeSalle 1999:29). This rapid growth can be explained by the explosion of the deer population, limitations on hunting, and the height of American development. The over-development occurring on previously forested lands has resulted in the "nature-culture" border being drastically altered, increasing the opportunities for human interaction at the epicenter of the deer tick's life cycle, from something as simple as a nature walk or picking up a fallen stick or branch from one's backyard (Walters 2003:16).

Habitat Fragmentation

Fragmented landscape illustrating forest patches of different sizes embedded within a non-forested matrix. Small patches appear to pose higher risk of exposure to Lyme disease.



As the amount of forest fragmentation decreases, which is indicated by forest area increasing, the density of infected nymphs also decreases. This is shown in the graph as area (ha) decreases (y), so does the density of infected nymphs (x). In an area that is fragmented, biodiversity has been severely decreased and humans have more environmental exposure to a more dense population of infected nymphs (Cary Institute of Ecosystem Studies 2016).

Due to constant development and simultaneous deforestation, Lyme disease exposure has increased significantly in the United States. The tick species *Ixodes scapularis,* formerly *Ixodes dammini*, and *Ixodes pacificus* are the vectors *of Borella burgdorferi* bacteria associated with Lyme Disease in the eastern U.S. and far western U.S., respectively (DeSalle 1999:53,62, USGCRP 2016). This tick species is found to be prevalent amongst the rodent and White Deer population in the United States. Hunting restrictions placed on deer have served to only drastically increase the size of their population in the U.S. and as development has removed buffers of forests between communities and the deer population, humans are now closer in proximity to deer, increasing their risk of exposure to ticks and, as a result, Lyme Disease.

The height of a tick's infectious stage occurs in the summer, the nymph life cycle, which is the small, immature life cycle of ticks. This timing directly coincides with periods of heightened tick and human recreational activity, putting them closer in contact with each other more frequently. Compounded by the effects of climate change, average temperatures and precipitation increasing, the creation of ideal environments for ticks are increasing, furthering human exposure.

This largely accounts for the spikes in the rate of Lyme disease cases in the past decade. However, as of February 16, 2016, what we know about Lyme disease is still growing.

According to researchers at the Mayo Clinic in Rochester, Minnesota, a new species of tick-borne bacteria has been discovered that causes Lyme disease, *Borrelia mayonii*. While presently only known to be found in the upper Midwest, it is entirely possible it can be found in other areas. The new bacteria was identified in 6 patients of Lyme disease, only one of which presented the most common symptom of Lyme disease, the EM rash. This is unusual as 70-80% of Lyme disease patients present with the rash. Three of the patients presented with skin rashes that were far more spread out than the typical EM rash and new symptoms were observed; nausea and vomiting (Weintraub 2016:1). Additionally, the patients presented with a much higher concentration of bacteria present in their blood, discovered upon diagnostic testing.

As Lyme disease is tricky to diagnose with what we already know, the discovery of a new disease causing bacteria has prompted the medical director of the microbiology lab at the Mayo Clinic, Dr. Pritt, to advise all patients with exposure to ticks in the geographic regions of Minnesota and Wisconsin, to undergo antibody and polymerase chain reaction testing to detect the presence of this new bacteria, especially if they do not have the typical EM rash (Weintraub 2016:1).

It is unknown as to why this bacteria has not presented before this time, but it is clear that what we know about Lyme disease is increasing, as well as the number of cases that will be reported annually. This is predicted to occur as the parameters of diagnosis of a disease that has been officially recognized for nearly 50 years, is still changing.

As it is already the most common vector-borne disease in the United States, this new evidence is alarming and indicative of further increases in vector-borne diseases.

As disruptions continually occur due to climate-related effects such as natural disasters, forced movement and displacement of communities, the natural barrier once existing between humans and vectors will be disrupted, therefore increasing exposure to the infectious diseases they carry.

Zika Virus

A current EID threatening global public health is the Zika Virus. First identified in Uganda in 1947 and first presenting in humans in 1952, the Zika Virus is an emerging vector-borne disease carried by the *Aedes* mosquito (World Health Organization). The symptoms of Zika include mild fever, headaches, maculopapular rashes, joint pain (anthralgia), muscle pain (myalgia), extreme fatigue (asthenia), and non-purulent conjunctivitis; all of which can last anywhere from 2 to 7 days post-mosquito bite. There is no treatment or vaccine currently available for Zika and the best protection against Zika is limiting exposure to mosquitoes and transmission through their bites.

Outbreaks of the Zika Virus were reported from the Pacific in 2007 and 2013 and over 13 countries in the Americas in 2015, demonstrating the virus' geographic expansion. The Aedes species of mosquito responsible for carrying the virus has been confirmed to already exist in 30 of the United States (Belluck and McNeil). The greatest risk to the human population is the sharp increase of infant microcephaly corresponding to outbreaks of Zika virus in Brazil.

In 2013 in French Polynesia and 2015 in Brazil, public health authorities reported possible auto-immune and neurological complications associated with Zika. In Brazil there has been a sharp increase in the number of Zika Virus cases as well as an increase in the number of infants born with microcephaly in areas of northeastern Brazil (World Health Organization). So far, the Brazilian government has reported 4,186 cases of microcephaly, but initially only 6 of these 4,186 cases have been strongly linked to the Zika Virus. The Director of the Department of Communicable Disease Surveillance in Brazil's Ministry of Health, Claudio Maierovitch, stated this link was established through lab testing of amniotic fluid and other tissues which confirmed genetic material from the Zika Virus was present in the mother and infant (Dina Maron 2016:1,Oliver Tickell 2016:1).

Margaret Chan, Director General of the World Health Organization, has also publically stated that retrospective analysis of the Zika Virus outbreaks in French Polynesia also showed an increase in neurological impairment of children and that the virus is capable of transcending the placental barrier (Maron 2016:1).

Citing this connection and other insurmountable data from further scientific study and research, the correlation between the Zika virus and microcephaly was officially accepted and acknowledged, as published in the New York Times, on April 13, 2016 by the Centers for Disease Control and Prevention (Belluck and McNeil 2016).

Section II: Disruptions in At-Risk Geographical Locations

While the seriousness, severity, and disruptive potential infectious diseases can have on the human population is evident, it is also critical to see the connection to public health in the United States. Climate change will impact all areas of human life, but there are areas of the United States that are at higher risk for disruptions caused by climate-related factors such as flooding and infrastructural damage due to frequent and severe storms. Targeting and analyzing the underlying vulnerabilities will allow us to pinpoint the types of ecological intervention necessary to prepare for and mitigate the effects of hazard events and infectious disease.

The most vulnerable populations in the United States are located along the country's coastline, isolated rural areas, floodplains, and impoverished urban areas (U.S. Global Change Research Program 2016). These climate-related factors cause disruptions that will disproportionately affect these areas and increase the vulnerability of these communities and their exposure to infectious diseases.

Coastal Areas

Coastal areas are extremely sensitive to the effects of climate change. Climate change causes sea level rise, the intensity and frequency of coastal storms, an increase in average levels of precipitation, and an increase in oceanic temperatures. Additionally, the anthropogenic and increasing concentrations of carbon dioxide in the atmosphere are causing the ocean to absorb more of this atmospheric gas, causing greater ocean acidification.

These impacts only serve to compound factors already threatening coastal areas; issues such as erosion of the shorelines, coastal flooding, and water pollution. In the 20th century, the global sea level rose by approximately 7 inches and are projected to increase by approximately 20-39 inches by the end of the 21st century (Environmental Protection Agency 2016).

A significant rise in sea level can cause a detrimental increase of salinity in an ecosystem's groundwater and a shift in salt water further upstream, thus affecting the potability of water. Without desalination, a large amount of water sources can become undrinkable, creating a scarcity of resources (EPA 2016).

A 2012 report from Climate Central's Environment Research Letters has predicted that, as a result of projected sea level rise, 3.7 million residents in 2,150 coastal areas of the United States could experience damaging floods from storm surges brought on by global warming (Jacobson 2012). The report's data was pulled from the United States' Ecological Survey in order to map areas along the continental United States within one to ten feet from the water at high tide (Jacobson 2012). Based on this data, Florida, Louisiana, California, New York, and New Jersey have the largest populations in the potential “flood zone”.

The United States has already experienced considerable storm damage in New Orleans, Louisiana post-Hurricane Katrina. The August 29th category 3 hurricane, connected with sustained winds of 125 miles per hour, was ultimately responsible for the deaths of 1,833 people. Additionally, the storm had a massive economic impact, the cost of damages estimated at $151 billion (U.S. Census Bureau 2015).

While the destruction and impact of Hurricane Katrina was horrific, Louisiana is not the only state whose inhabitants need to be concerned. Coastal states with high population densities such as New York and Florida, the state with the highest population density in direct danger of flood damage, also face significant flood concerns (Jacobson 2012). Based on current projections, in low-lying areas of coastal Florida sea level rise could cause water to encroach 400 feet or more inland, causing severe flooding.

Not only will shoreline homes be flooded, but the National Resource Defense Council (NRDC) finds that the supply of underground freshwater drinking water supplies that is used to feed cities and agricultural centers could be endangered by saltwater contamination (Fiedler 2001). Without equitable access to safe water, sanitation and hygiene will become limited or nonexistent, food will become scarce, and self-storage of water will increase. All of these factors lead to increases in vulnerability to waterborne, food-borne, and vector-borne infectious diseases based on the disruptions caused by climate-change related impacts.

In addition to availability of potable water, the other large problem in coastal areas of Florida is the impact of climate change on public health. Particularly worrisome is the fact that the elderly are significantly vulnerable to negative climate-related health effects as Florida's senior citizen population is already the largest portion of the state's population.

Rural Areas

Rural areas are particularly at risk for the negative effects of climate change generally due to their isolated nature. Isolation is further compounded by aging population demographics, limited economic diversity, and increasing poverty rates. All of these factors together increase rural areas' vulnerability to climate-related stressors, including negative impacts on the public health of these regions. In recent years, climate-related

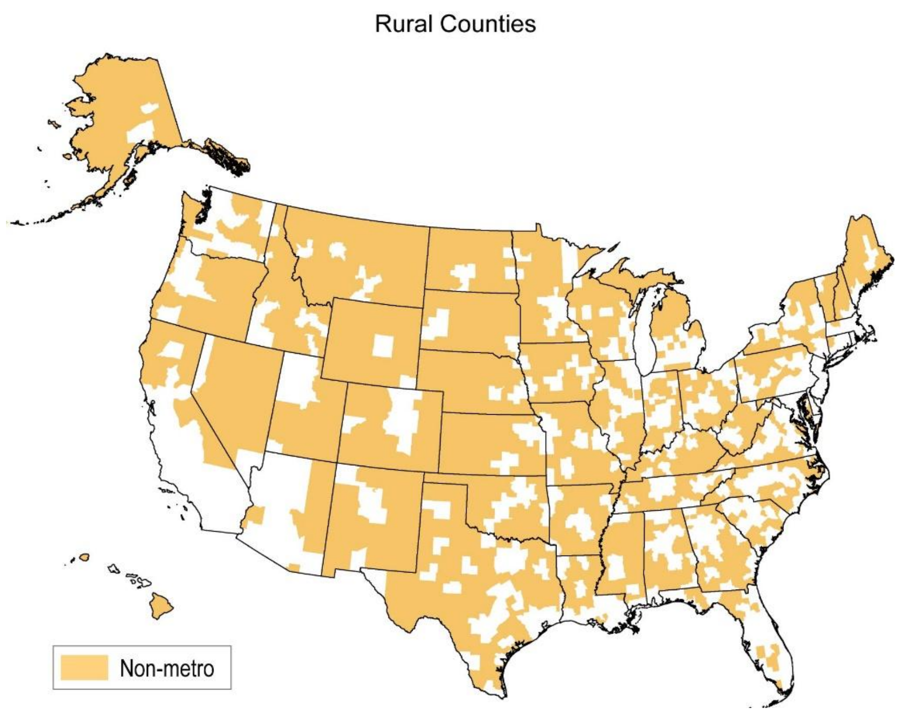


Figure 14.1: Although the majority of the U.S. population lives in urban areas, most of the country is still classified as rural. In this map, counties are classified as rural if they do not include any cities with populations of 50,000 or more. (Figure source: USDA Economic Research Service 2013[39]).

weather patterns such as increased droughts in dry seasons and increased severity and frequency of flooding have caused crop and livestock losses and infrastructural damage, especially to levee and road systems (Melillo et al. 2014, National Climate Assessment 2016).

Based on predictions and projections of climate-data, the new pattern of increased storm activity will accelerate the rates of soil erosion and, as a result, decrease water quality. Decreased water quality, as a result of increased phosphorous and nitrogen levels, will cause competition for water resources to increase. With agricultural, industrial, urban, and household needs, the water supply will suffer dangerous stress. The stress on the water supply can lead to contamination of public drinking water, resulting in outbreaks in waterborne infectious diseases such as cholera and cryptosporidiosis discussed above.

Increasing temperatures will also negatively affect those living within these rural regions as areas such as the Midwest and Great Plains will experience longer growing seasons, placing more workers outside. Increased time outdoors will expose agricultural and outdoor laborers to an increased population of vectors, and therefore, vector-borne diseases, namely Lyme disease.

In terms of public health related predictions, the population of rural communities is particularly at risk due to pre-existing demographic information. Rural communities are generally characterized by higher unemployment rates, less diversified economies, and fewer socioeconomic resources allocated for climate-related resiliency (National Climate Assessment 2016). Demographically, rural areas are comprised of older, less educated, and poorer residents. With less access to educational opportunities and opportunity for quality health care, the communities of isolated rural areas are at an increased risk of economic and health challenges. Concurrently, these areas are also stressed by the lack of adequate public health infrastructure and disaster response mechanisms.

Floodplains

Floodplains are defined as flat areas of land located next to a river or a stream. As their name indicates, floodplains are at high-risk of flooding, mainly due to their flat structure and adjacent location to bodies of water. In the United States, there are several floodplains of considerable note, including New Orleans and St. Louis, Missouri.

Urban planning in these areas is intended to protect floodplains and residents from considerable damage, incorporating limited infrastructure and architectural endeavors on floodplain sites and implementing levee and other barrier systems to prevent as much damage as possible. However, even though these barrier systems are implemented, evacuation procedures, emergency shelters, and strict building codes are still necessary. Even with all of these mandatory precautions in place, major flood damage is still entirely possible, especially as we continue to see climate-related impacts in the United States. This imminent flood damage will also contribute to the increased occurrence and transmission of infectious disease.

The St. Louis, Missouri floodplain is located between the Mississippi and Missouri Rivers and has a history of flooding. The area experienced severe damage in the Great Midwest Flood of 1993 when 40% of the surrounding county was flooded. This area suffered more damage as recently as December 2015-January 2016 with intensive flooding, the river having crested at approximately 42 feet, nearly reaching the 1993 flood levels. (Rice 2016).

While voluntary evacuation was enacted and residents prepared their own homes with sand barriers and moving valuable belongings, the flood still left considerable damage in its wake. Most notably was the overflow and power outage that occurred at the local wastewater treatment plant, releasing tons of untreated waste into the local Meramec River, endangering the surrounding population with harmful bacteria. In a typical day, the plant treated approximately 6 million gallons per day, but during the flood was inundated with over 24 million gallons. The release of harmful bacteria into the local water supply was severe enough for the local state department to release a boiling order for water use (St. Charles County website 2016, Rice 2016).

Floodplains in the United States are already at an increased risk of experiencing flooding, without the added effects of climate-related increases in weather intensity. With increased levels of participation and the severity of storms affecting these vulnerable areas, waterborne infectious diseases are inevitable.

Impoverished Urban Areas

Urban areas are also at increased risk for climate-related health effects. Due to the extensive surrounding of concrete and cement as well as poor air quality, higher temperatures are pervasive in urban areas. Various urban areas are often known as “urban heat islands” as temperatures are higher than their rural surroundings due to human activity. The higher temperatures and poorer air quality contribute to the poor and chronic ill health of urban residents. It has been projected that temperature changes will account for a 50%-91% increase in heat-related deaths by the 2080s in Manhattan alone (Melillo et al. 2014, National Climate Assessment 2016, USGCRP 2016:377).

Recent urban ecology studies performed in Baltimore and Washington D.C. by the Rutgers Center for Vector Biology have elucidated the fact that economic disparities are a good indicator of the increased presence of vectors such as the Asian tiger mosquito. In urban areas experiencing a high level of decay, such as West Baltimore, the number of mature Asian tiger mosquitoes is approximately three times higher than in wealthier neighborhoods in Baltimore (Mooney 2016).

The abundance of trash and abandoned buildings in degraded urban areas create a plethora of suitable habitats for mosquitoes, as these receptacles create persistent stagnant pools of water. This causes a large public health threat as the increase of mosquitoes can also cause an increase in vector-borne infectious diseases such as the Chikungunya and Zika viruses. “The problem posed by waste situations such as this is that key mosquito species have adopted survival and reproductive strategies that depend upon the artificial urban environments created by humans. You get a handful of species that can breed in that type of habitat, and when they do so they of course have no competitors and no predators, and you get huge population abundances" (Mooney 2016).

In socioeconomically disadvantaged areas, the elevated presence of these infectious diseases goes largely untreated due to a lack of access to adequate medical care offering testing for these diseases (Mooney 2016). Also, these communities are already suffering various environmental disparities and injustices; suffering from exposure to pollution and toxic materials causing chronic illnesses. Therefore, symptoms can easily go unnoticed by individuals, exacerbating or magnifying an environmental health justice issue.

Section III: Climate-Related Health Impacts as an example of Environmental Justice

Environmental Injustice

Preparation for climate-related illnesses goes beyond building a more resilient future, it is also a matter of justice. The Environmental Protection Agency defines environmental justice as the fair treatment and meaningful involvement of all people, regardless of factors of race, color, national origin, or income (2016). The stipulation for fair treatment and meaningful involvement extend through the development, implementation, and the enforcement of environmental laws, regulations, and policies. (EPA 2016) Therefore, no group of people should be disproportionately affected by negative environmental consequences that result from any industrial, governmental, or commercial operations or policies. Environmental justice also requires everyone to have an opportunity to participate in the decision making processes that may affect the health of their environment and public health.

In analyses of case studies of climate-related health impacts, it is evident that certain portions of the population are disproportionately vulnerable to and affected by climate-change related health impacts. In 2000, public health studies in the United States showed that the prevalence of asthma was 104 per 1,000 White persons and 122 per 1,000 Black persons, with mortality rates of asthma being approximately 35% higher among Black persons than White persons (National Climate Assessment, USGCRP 2016). This disproportionate suffering needs to be analyzed further in order to afford everyone with the same rights to environmental justice. Factors of socioeconomic status, the accessibility of adequate infrastructure, accessibility to healthcare, social capital (the shared knowledge, skills, and social cohesion of a community), and demographics characteristics all take part in a community's adaptive capacity in terms of climate-related health impacts.

A population's vulnerability to negative climate-related health impacts include an analysis of exposure to changes, sensitivity to these changes, and their adaptive capacity to cope with these changes (National Climate Assessment 2016, USGCRP 2016). The most at-risk populations in the United States are the socioeconomically disadvantaged, communities of color, immigrant groups, Indigenous populations, children and pregnant women, the elderly, the disabled, and the chronically ill (NCA 2016, USGCRP 2016).

Studies have shown that the average number of life years lost from climate-related death was 35% greater for Black Americans than White Americans, indicating a very serious, disproportionate suffering (NCA 2016, USGCRP 2016). There are several areas of environmental public health justice case studies that serve to further show a disproportionate risk of contracting infectious disease in the socioeconomically disadvantaged and communities of color.

Underlying socioeconomic and health disparities of these communities increase their risk of infectious disease, posing an environmental injustice on specific portions of the United States.

Health Inequalities

In order to understand the relationship between climate-related health impacts and infectious disease, it is important to understand how underlying health conditions can further compound the risk of infectious disease. The functioning of the human body is dependent upon the natural state of our own microbes, first acquired during birth and continuing to develop within the first few weeks after birth, changing as we are exposed to different environments and, therefore, are introduced to new environmental microbes. When the microbes of our bodies are introduced to new elements or disturbed, exposure to pathogens increases and so does the susceptibility to illness and disease (DeSalle 1999:40).

While it can be argued that global public health has improved in the last century to increase life expectancy while decreasing infant mortality, it has also become clear that human health in the United States, in general, is declining.

Over ⅓ of the U.S. population has been diagnosed with a chronic illness such as cancer, autism, diabetes, and infertility (Myers and Raffensperger 2006:7). The number of asthma diagnoses, alone, has doubled within the past twenty years. Specific types of cancer have also increased in prevalence; breast cancer diagnoses increasing by approximately 50% in 50 years (Myers and Raffensperger 2006:7).

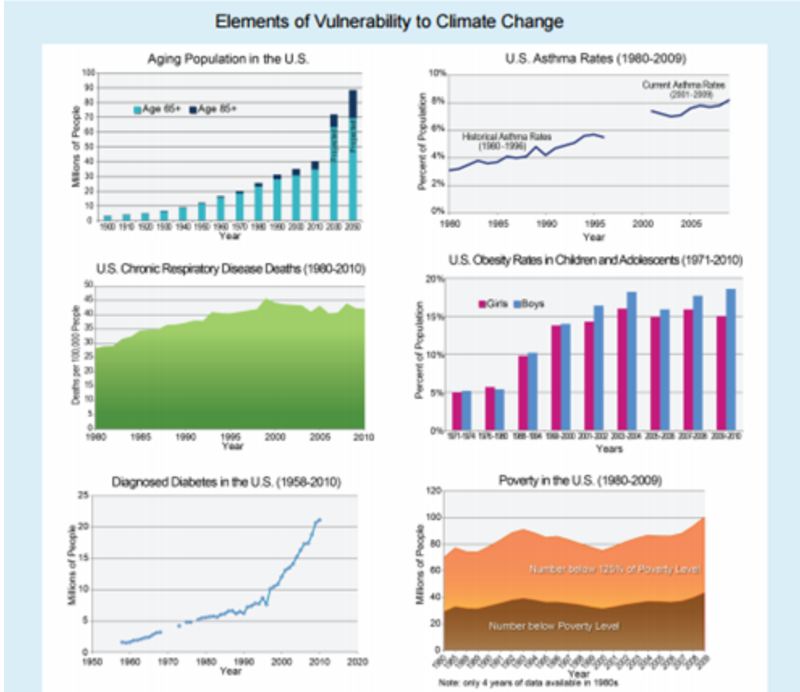


Figure 9.9. A variety of factors can increase the vulnerability of a specific demographic group to health effects due to climate change. For example, older adults are more vulnerable to heat stress because their bodies are less able to regulate their temperature. Overall population growth is projected to continue to at least 2050, with older adults comprising an increasing proportion of the population. Similarly, there are an increasing number of people who are obese and have diabetes, heart disease, or asthma, which makes them more vulnerable to a range of climate-related health impacts. Their numbers are also rising. The poor are less able to afford the kinds of measures that can protect them from and treat them for various health impacts. (Data from CDC; Health E-Stat; U.S. Census Bureau 2010, 2012; and Akinbami et al. 2011[137]).

One of the greatest indications of declining human health in the United States is the increasing rate of obesity. In the past decade, the rate of obesity in the United States has increased approximately 132%, increasing from about 12% of Americans in 1990 to a staggering 27% in 2011 (Johnson 2011:1). Over 29 million adults in the U.S. have diabetes and another 86 million adults have been diagnosed with prediabetes (Robert Wood Johnson Foundation 2016). The CDC has predicted that by the year 2050, one in every three Americans will be diagnosed (Johnson 2011:1).

This statistic is further compounded by the correlation of obesity to the ever increasing number of households living below the poverty threshold. The U.S. Census Bureau report calculates that approximately 21% of American children under 18 are living in poverty. This poor condition of living leads to a lack of access to comprehensive medical and health care, limited availability of healthy food options, and far fewer choices of educational and physical fitness opportunities than their socioeconomically advantaged counterparts (Johnson 2011:1).

Obesity has already been extensively linked to health implications such as lung functioning, exercise capacity, weakened respiratory control of airflow, and chronic inflammation of the upper and lower respiratory tracts. Additionally, obesity is linked to cardiovascular diseases and increases overall mortality. This is further magnified by the increasing average temperatures of global warming, but it is also important to note that emerging evidence also shows a link between obesity and the increased risk of infection (Smith, Woodward, Campbell-Lendrum et al. 2008).

Leptin, a hormone that controls satiation, links a human's nutritional state to the functioning of their immune system, regulating the system's response to inflammatory and infectious stimuli (Falagas and Kompoti 2006:1). When an individual has a leptin deficiency, such as is present in an obese individual, they are more susceptible to infections of organs and greater organ systems, as has been shown in animal subjects.

It stands to reason that obesity weakens the human body's immune responses, throwing it off of its natural microbial balance, which not only causes all of the aforementioned health problems, but also makes the human body far more susceptible to contracting infectious disease (Falagas and Kompoti:1). With 27% of the American population currently obese, the United States population is more vulnerable than ever.

It is also worth mentioning that clinical trials have shown obesity to increase chances of non-responsiveness of vaccines in human subjects. Obesity is categorized as a low-grade chronic inflammatory illness. There are two possible explanations for the non-responsiveness: the pro-inflammatory state of obese individuals counteracts immunogenicity and efficacy vaccines and/or dietary intake may have effects on the gastrointestinal microbiota resulting in a "leaky gut". This allows for the possibility of the translocation of bacteria, affecting levels of immune activation in obese individuals (Young, Gray, and Bekker 2013).

While further studies need to be conducted, non-responsiveness in obese candidates were reflected in seasonal trivalent influenza vaccines (TIV), the tetanus toxoid vaccine, as well as early HIV vaccine trials performed in Cape Town, South Africa (Young, Gray, and Bekker 2013:1). The further analysis of this link is of critical importance to vaccine development and re-development in the face of emerging infectious diseases.

Obesity is an example of socioeconomic factors being tied to a community's health, but it is not the only factor present in this relationship. Environmental enteropathy (EE) is a common health condition observed in socioeconomically disadvantaged areas with poor sanitation and hygienic standards. A subclinical condition, environmental enteropathy is caused by exposure to constant fecal-oral contamination (Korpe and Petri 2012). This constant exposure results in intestinal inflammation and structural damage to the small bowel. This generally causes functional damages of the gut such as increased intestinal permeability, decreased gut immune function, stunted growth, and malabsorption.

Environmental enteropathy is an example of the consequences of both environmental and health systems being inadequate. Not only does EE occur in areas of the world lacking access to public health infrastructure and basic standards of sanitation, but it also affects public health interventions against infectious disease (Korpe and Petri 2012). The malfunction of the gut causes a myriad of health issues such as decreased mucosal immunologic function, increasing the chances of pathogen exposure and illness (Korpe and Petri 2012). Chronically decreased mucosal immunity also decreases the efficiency of vaccines in affected individuals, increasing individuals' risks of contracting an infectious disease.

With the United States being more vulnerable than ever, it is important to also examine portions of the population exposed to and already suffering from increased risks, caused by underlying health inequalities. Obesity is not the only factor increasing the American population's susceptibility to infectious diseases.

In 2016, race and ethnicity are still factors of socioeconomic status and health status. While children and the elderly are the most vulnerable populations, globally, climate related mortality statistics still vary in terms of gender, socioeconomic status, and race. In the United States, Black Americans are reported as the most vulnerable portion of the population to heat-related deaths and during pregnancy, women are more vulnerable to infectious diseases such as malaria, foodborne illnesses, influenza and now the Zika virus (CDC 2016, Smith et al. 2008). Physiologically, children are more vulnerable to climate related illnesses such as malaria, diarrhea, and poor nutrition (Smith et al. 2014).

Another indicator of declining health within the United States is the increasing rate of asthma. In 2010 it was recorded that at least 27.5 million Americans had asthma, implicating every state (Smith et al. 2014). As we continue to understand and track the effects of climate change, climate-related health impacts will likely continue to flourish. Increased temperatures coupled with increased air pollution will cause an increase in respiratory-related illnesses, hospital visits, and death. While every state is certainly implicated in the rates of increased asthma and respiratory illnesses, we see this problem, once again, occurring disproportionately in vulnerable populations.

Communities of Color:

Perhaps one of the most recent and heinous examples of this disproportionate suffering is the use of FEMA's, the Federal Emergency Management Agency, deployment of toxic trailers to those already suffering and displaced from Hurricane Katrina. On August 29th, 2005 category 3 storm Hurricane Katrina decimated 130 miles of Louisiana coast and mainland (Collectif Argos 2010). The hurricane, with sustained winds of 125 miles per hour, caused approximately 1,833 deaths and $151 billion in damages (U.S. Census Bureau 2015).

A mere 24 hours after the levee failure in New Orleans, sixty trailer companies were contracted by the Federal Emergency Management Agency (FEMA) to provide housing for displaced individuals whose homes were lost to the flooding. Through these contracts 120,000 trailers, costing $2.7 billion, were commissioned (U.S. Census Bureau 2015, Smith 2015).

While these trailers were built to provide safe shelter to those suffering in the wake of the tragedy of this natural disaster, they also exposed these individuals to highly dangerous levels of formaldehyde. Used in construction of particleboard, formaldehyde fume exposure is concentrated in trailers due to their small size and low ceilings (Smith 2015).

While the National Institute of Health (NIH) declared formaldehyde to be an anticipated human carcinogen in 1981, the Department of Housing and Urban Development did not move to regulate the levels of formaldehyde for travel trailers or motor homes, as they were built for temporary lodging and recreation use (Smith 2015). This presents a problem when they are provided as the only option of housing for disaster relief, forcing individuals into toxic environments.

Malcolm Byrnes' work in October of 2013 further addressed this injustice, stating, "more than 8 years on, the city and its African-American population still have not recovered fully. This reality highlights an important truth: the disturbances that accompany climate change will first and foremost affect minority communities, many of whom are economically disadvantaged".

Another issue of justice currently occurring, and only projected to become far worse, is within the incarcerated population of the United States. Similar to refugee settlements, prisons create a forced environment in which forced cohabitation and interaction are a part of daily life. There are several potential outlets for severe disruption in this environment. Clearly, prisons are environments that are primed for outbreaks of infectious disease, inmates in close quarters with limited access to sanitation and hygiene. However, with rising sea levels, prisons located on the coasts of the United States face the added threat of flooding.

An example of these concerns has been manifesting at Riker's Island prison complex, located in New York's East River, for decades. Currently, the 415 acre complex on Riker's Island is host to approximately 10,000 people, a major concern as the complex is already extremely vulnerable to flooding. In 1975, a large class action lawsuit was filed by the Legal Aid Society against Riker's and the Department of Corrections due to the unhealthy heat conditions at the complex (Rakia 2016).

Since this time, more reports of poor infrastructural and public health concerns have surfaced. As a part of ongoing investigations, NYU School of Medicine's own Susi Vasallo, has conducted several studies of conditions at Riker's and noted quite a few areas of concern in addition to dangerously high temperatures (Rakia 2016). Vasallo's studies reported severely high temperatures in the complex built from concrete, steel, and cinder blocks, stiflingly warm solitary confinement units without air conditioning capabilities, damaged underground pipeline systems causing water shut-offs and backup of sewage and waste, inadequate ventilation systems, and frequent systemic, seemingly perpetual, flooding of several centers of the greater complex (Rakia 2016).

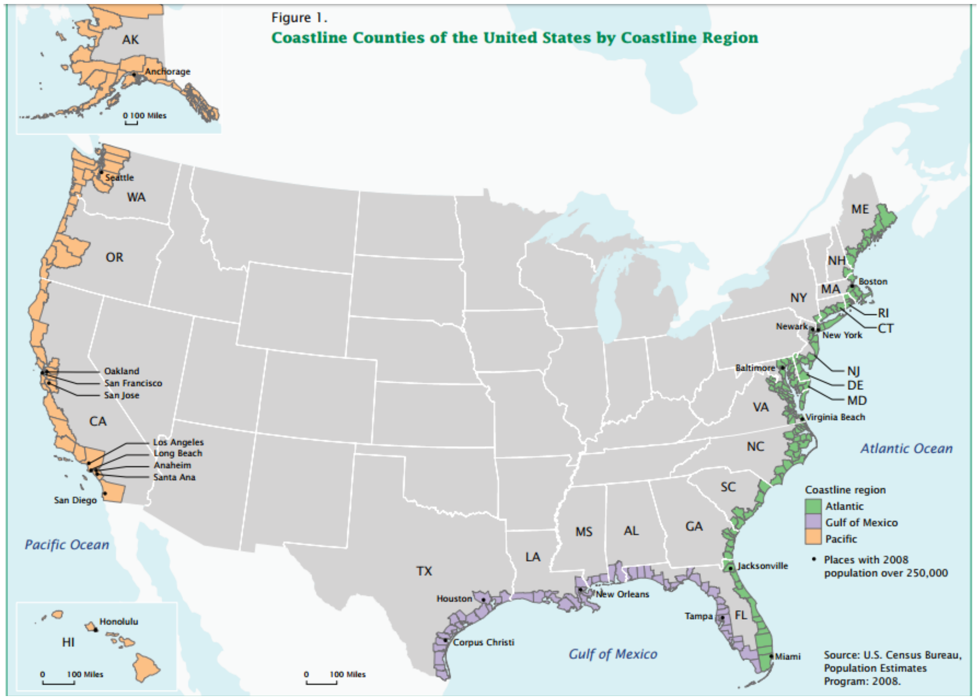
This is clearly an environment that is ripe for infectious disease outbreaks associated with climate change; poor conditions exacerbated by compounding factors of increased instances of rising temperatures, flooding, and stagnant pools of water.

While clearly a public health issue, this stems far greater into an example of environmental injustice. Rikers, for example, hosts approximately 10,000 individuals on a daily basis, 90% of these individuals are Black or Latino. A majority of these individuals have not even been formally convicted and sentenced for committing a crime, but are awaiting trial, sometimes for years at a time (Raika 2016). The data collected on those inmates who have been formally convicted shows that a majority of these inmates are serving time for low-level offenses, serving short-term sentences.

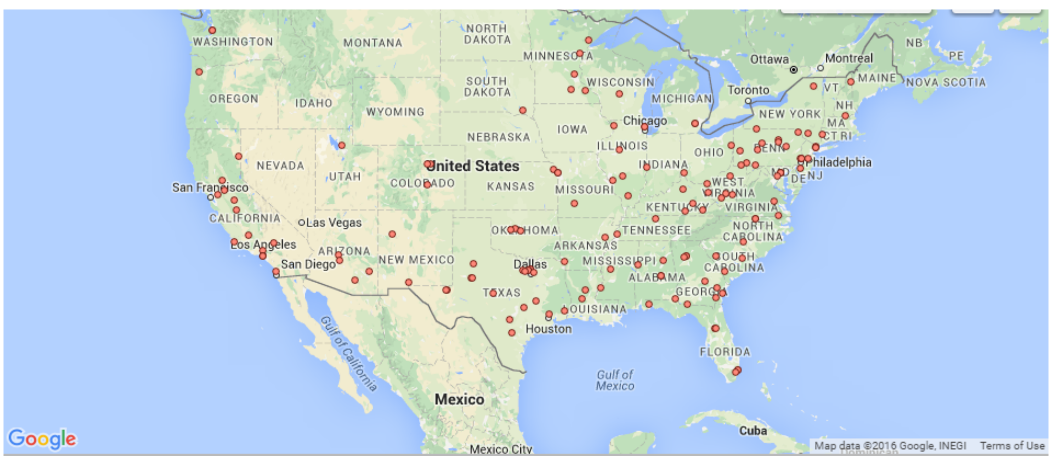
Essentially, the inmates, 90% of whom are minorities in the United States, are subjected to threatening environmental and public health conditions, a majority of which have not even been convicted of a crime (Rakia 2016).

Further, as of 2011 with storm Hurricane Irene, it became public knowledge that the Department of Corrections did not have an evacuation plan for the individuals on Riker's Island. Had there been major flooding and infrastructural damage, the inmates would not have had a way to escape these conditions, condemning them to serious injuries, illnesses, and even death (Rakia 2016).

This a serious problem as it is not endemic to Riker's Island, it is a very real possibility for any and all institutions located on America's vast coastlines. A considerable number as there are 3,283 correctional facilities in the US and, referencing the following graphics produced by the U.S. Census Bureau and the U.S. Department of Justice, there is a significant number of coastline in the U.S with corresponding correctional facility locations (Federal Bureau of Prisons 2016, U.S. Census Bureau 2008).



These graphics show the coast of the United States and the corresponding Federal Board of Prisons correctional facilities. (Federal Bureau of Prisons 2016, U.S. Census Bureau 2008).



Refugees

In 1948 the United States Congress enacted the first refugee legislation, the Displaced Persons Act of 1948 and in 1980 passed the Refugee Act of 1980, standardizing resettlement services for all refugees admitted to the United States. This act also provided the basis for the partnership of the Bureau of Population, Refugees, and Migration (BPRM), the Department of State, the Department of Homeland Security, and the Department of Health and Human Service's Office of Refugee Resettlement to create the United States Refugee Admission Program (Refugee Council USA). Since 1975, this system has welcomed over 3 million refugees to the United States (Batalova 2015, UNHCR 2016).

In the past fiscal year, FY 2015, the United States resettled 69,933 refugees and the Obama administration has proposed to increase the number of refugees accepted in the United States from 70,000 in fiscal year 2015 to 85,000 in fiscal year 2016, and raise it again to 100,000 in fiscal year 2017 (Batalova 2015).

According to the U.S. Department of State, the first step in the refugee process is for individuals to register with the United Nations High Commissioner for Refugees (UNHCR) in their country of arrival. The UNHCR has the ability, and mandate, to provide refugees with international protection while the organization determined whether or not an individual qualifies for refugee status. Post-investigation, the UNHCR will either have individuals returned to their home country, integrated locally in the arrival country, or third-country resettlement (UNHCR 2016).

While this process has certainly assisted resettlement in the United States, due to the increasing effects of climate change, the United Nations projects that by the year 2050, 150 million people will become refugees, specifically due to the effects of climate change (Collectif Argos 2010). While the United States is not the only country that accepts refugees, the U.S. is the world’s leading resettlement country. An increase in refugee populations is a challenge to public health infrastructure, especially on this large of a scale.

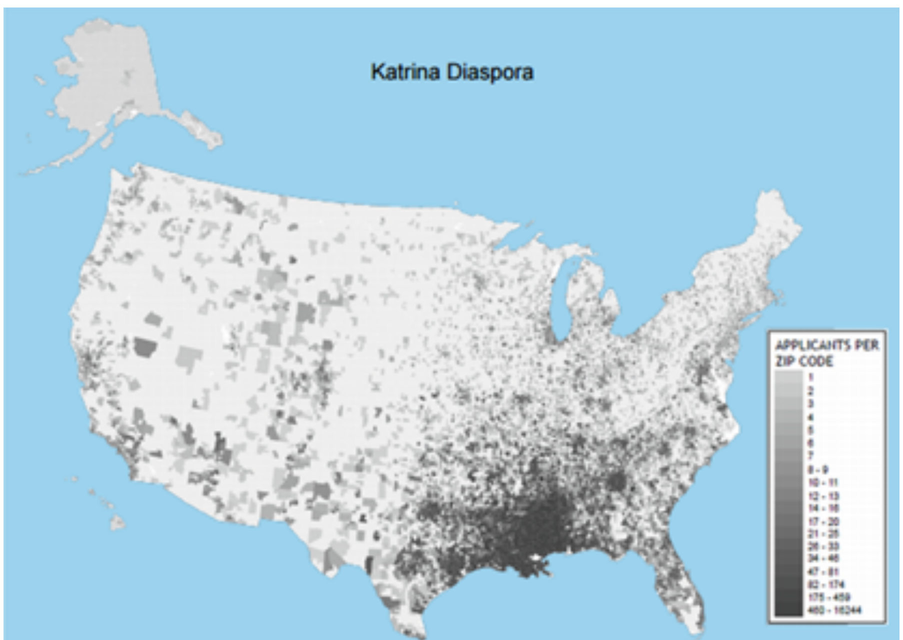


Figure 9.10. This map illustrates the national scope of the dispersion of displaced people from Hurricane Katrina. It shows the location by zip code of the 800,000 displaced Louisiana residents who requested federal emergency assistance. The evacuees ended up dispersed across the entire nation, illustrating 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 (Ch. 2: Our Changing Climate, Key Message 8). (Figure source: Kent 2006[155]).

Refugees entering the United States from other countries are not the only populations in need of resettlement. The impacts of climate change will necessitate populations within the United States to relocate in-land, as well, as severity and frequency of storms increase and sea levels begin to rise; thus threatening America's coastline, similar to the events of Hurricane Katrina in Louisiana and the necessary relocation of over 30 native villages in Alaska (NCA 2016, USGCRP 2016).

While there are standards to which refugee camps and settlements are meant to be kept, as provided by the UNHCR, there are still concerns that need to be addressed. The UNHCR is well aware that in times of emergency, living conditions in camp settings can be less than ideal, presenting favorable environments for epidemics of communicable diseases.

The most pressing issues are sanitation, availability of water, and clean living spaces and often in cases of emergency, these needs are barely met (UNHCR 2011). The UNHCR stresses prevention as the most important process in addressing infectious diseases, creating the necessity of health surveillance in camps and a communication structure to maintain the flow of information regarding this surveillance.

However, refugee environments can be extremely difficult for a variety of reasons. For example, the presence of poultry in refugee camps and the increased potential for the outbreak of highly pathogenic avian influenza (HPAI) (UNHCR 2011). In many refugee settings, contact with animals is increased and can create any number of vector-borne, waterborne, and food-borne illnesses. As animals are often raised and kept for income-generating activities and create several positive effects, such as an increase in general well-being, their removal from these settings is not prioritized and continued existence of these practices is supported by the UNHCR.

Another point of concern for displaced people is the effect of changing diet and nutrition on an individual's immune system, creating further vulnerability within this population to climate-related illness. When a population is forced to leave their homeland and settle elsewhere, this population is also forced to leave behind their traditional diet, which has led to inevitable rises in serious chronic illnesses such as cancer, diabetes, allergies, and heart disease (Nabhan 2004:86). An increase in underlying health vulnerabilities will only make these populations more susceptible to infectious disease.

In 2014, United States President Barack Obama, partnered with international organizations, non-governmental organizations, and 50 nations from around the world, launched the Global Health Security Agenda. The Global Health Security Agenda was established in order to strengthen not only the response to, but also the prevention and detection of infectious disease threats, globally (Sow and Barnett 2016). While the launch of the agenda is certainly timely and necessary, it is severely lacking in potential and practicality. The agenda largely focuses on laboratory studies and global surveillance efforts to track and better understand infectious disease.

While certainly these tactics are worthy pursuits and of great importance to build resiliency against this issue, it misses very basic, very necessary programming. The most basic, most affordable, most efficient, and most sustainable approach to preventing infectious disease is providing at-risk communities with access to safe water, soap, and sanitation. Without the provisions for, and the prioritization of sustainable safe water and sanitation to communities, these pursuits, however well intentioned, will fail to prevent infectious disease outbreaks (Sow and Barnett 2016). This is an issue of prioritization and governance.

Section IV: Where do we go from here?

Epistemic Injustice, Right to Know.

It is clear that the Earth's climate is changing and that global warming is, in fact, a reality. With the assistance of some predictive public health work, we can see that there are enough systems breakdowns occurring that the state of public health in the United States will be tenuous, at best, and incapable of handling these health burdens in a relatively short period of time. What is not clear is how we are going to prepare and build resilience for the eventualities of increased and emerging infectious disease.

The public health field will need to implement systems of funding, public health surveillance and monitoring, for effective results and feedback, and effective programming for disease prevention.

It is evident that communities of color and migrants are disproportionately affected by climate-related health impacts and this act of environmental injustice needs to be addressed. Compounding this environmental injustice is the further burden of epistemic injustice experienced by communities of color, refugees, and Indigenous communities.

Epistemic injustice refers to unfair and unequal distribution of education and/or knowledge. According to Miranda Fricker, author of Epistemic Injustice: Power and Ethics of

Knowing, epistemic injustice is, “a wrong done to someone specifically in their capacity as a knower” (2007).

Somewhere along the line, it was decided for these communities that only those who could afford an education would be the ones who can afford to understand all aspects of what is occurring in our environment. They would be the only ones who are truly consulted on policies and regulations regarding their health and the health of the environment and allowed to participate, fully, in the making of these decisions.

Environmental risk management-risk assessment policies in the United States began in 1983 in order to evaluate the potential risk of harm caused to the environment and on human health. However, not until more recently has it become far clearer that, in order to fully evaluate and assess environmental health risks, the scientific community and the local, vernacular communities of stakeholders must all be involved in an iterative adaptive management process in order to address these issues (National Climate Assessment 2016).

Critics of public participation and citizen science frequently argue that the cost of involving all stakeholders does not offer enough benefit or that stakeholders are not educated enough to offer valid knowledge to the subject of environmental health risks. This is an injustice, as it takes away the rights of these stakeholders as knowers. There is far more knowledge than raw scientific data and far more ways of knowing than what hard science can teach us. Traditional ecological knowledge and cultural knowledge is becoming a more widely recognized way of knowing and extremely useful in furthering scientific knowledge. Traditional ecological knowledge and cultural knowledge offer a better long-term perspective on a specific geographical location (Gagnon and Berteaux 2009), more than what scientific data can give us, because it comes from the collective inclusion of a group of people. Infectious disease can and will affect all of us, regardless of race, sex, or socioeconomic status. Therefore, the holistic inclusion of the public is necessary to fight for the future of mankind.

While there are certainly populations that shoulder a disproportionate amount of the burden of exposure to these diseases, there is not one population that is safe from the effects of climate-related infectious disease. With this in mind, it should become obvious that there is not one way to approach this issue, not one group of people with whom we need to consult. While this analysis focuses on the United States, climate-related infectious disease is a global threat requiring global approaches and solutions. With the increased advancements in transportation and globalization, exposure to infectious diseases increases enormously. While quarantine is a solution in some cases, it certainly is not economically feasible for the United States to operate in a quarantined state for an extended period of time. It also will not prevent infectious diseases from occurring domestically, as we have discussed through the presence of waterborne, foodborne, and vector-borne diseases resulting from alterations in the U.S. climate.

In order to approach these issues, the scientific community, the public health community, and individuals must all work cooperatively and concurrently. The best way to do this kind of work is to utilize “boundary spanners” in order to connect all of these spheres into an interconnected and communicating unit. Boundary spanners are trained mediators between the scientific and local communities. While they have knowledge of both hard science and governmental policies and regulations, they are also well versed and experienced in their assigned communities and, therefore, are trusted to span both of these boundary zones in order to ensure effective communication and collaboration.

International, federal, state, and local health organizations need to be on the same page in regards to public health surveillance and monitoring. Once a potential threat has been tagged, it must be passed through the chain of command in order to prepare all health organizations to prepare and manage their response to disease outbreaks. All health organizations need to take advantage of federal programs training medical personnel to understand the relationship between infectious disease outbreaks and environmental conditions, namely climate change.

The CDC's Climate Ready States and Cities Initiative began in 2009 to serve this exact purpose. The initiative is currently working with 16 states and 2 cities to assess atmospheric and epidemiological data to study climate impacts on public health in these areas. Preparation and the pursuit of resiliency will be key for outbreak management and human survival.

Furthermore, it will be necessary to supply vulnerable communities with community public health workers who can work closely with their local communities in order to promote educational awareness of environmental health and providing access to adequate medical care.

Public Health
(surveillance, programming, funding)

The best approach to mitigating the impact of infectious diseases on the population is to prevent them from occurring. Focusing on prevention requires significant involvement of the public health sector of the medical field. Currently, emphasis on disease prevention is very limited in the United States, our medical institutions focused more on disease and illness-care of the already clinically ailing (Schettler 2006). This approach is worthless in the face of increasing cases of infectious diseases.

If we fail to re-focus our efforts to prevention, our medical institutions will be inundated with the ailing and the suffering, overfilled and lacking in adequate resources. With the ease of transmission of waterborne, foodborne, and vector-borne infectious diseases, our current system cannot handle the public health outbreaks in the aftermath of hazard events or the rapid transmission of diseases aided by the processes of globalization.

In order to adequately address climate-induced infectious diseases, we need to be able to prevent them in order to mitigate their effects on the population. In order to do so, more emphasis must be placed on the surveillance and monitoring of global and domestic infectious diseases. Knowing where outbreaks of infectious diseases are occurring will allow us to make predictions of disease transmission in terms of location-- where a disease is heading and how this will affect the population in this area.

The United States Agency for International Development (USAID) further quotes the need for further ongoing research on climate change and infectious disease. The USAID recommends further study and surveys of wildlife in order to study disease and virus diversity with the possible illumination of which species of wildlife are most likely to host viruses with the highest risk of future emergence.

Surveys of this nature have historically connected the species most biologically similar to humans and in the closest proximity to highly populated areas to be the greatest risk to human health. Additionally, these studies must include the potential global transmission of these diseases due to processes of globalization, for example via air travel. This will allow for the surveillance of potential hotspots of infectious disease in terms of human-to-human transmission, allowing for more effective public health interventions to be allocated to prevent further spread of the disease.

Once the threat is known, resources can be allocated more efficiently and effectively. Waiting to provide resources and response until after a disease outbreak has already begun severely limits the effectiveness of the interventions local health organizations can provide. Surveilling and monitoring infectious disease is the only way to project what is to come and to prepare timely public health responses to these outbreaks.

Educational efforts and programming are also required, especially in communities of need. It is clear that socioeconomically disadvantaged communities and communities of color are disproportionately burdened by climate-related illnesses.

Working directly within these communities will allow public health workers to assess and address the underlying vulnerabilities these communities are already facing, allowing the effects of infectious disease outbreak to be better predicted and, with effort and resource allocation, prevented.

As previously mentioned, the most cost-effective, efficient, and sustainable resources we can promote and provide are the basics of hygiene and sanitation: establishing and maintaining community access to soap and clean water. In the aftermath of a hazard event such as a severe storm and flooding, many infectious disease outbreaks will be caused by the contamination of the public water supply and a lack of access to potable water and soap.

These are the basics of human survival, the cheapest yet most effective interventions we can offer to prevent, or at least mitigate the effects of, infectious disease. Yet, somehow, we still lack the programming to necessitate these provisions, a retrospective failure which needs to be immediately corrected.

Additionally, there exists a fundamental gap in our current approach to climate-induced illness and disease, as our medical infrastructure is too narrowly focused and single-minded to provide the tools for the health of our communities. This issue is environmental, but it also affects the public health of all humankind. We cannot hope to address the pressing issue of the relationship between climate change and infectious disease patterns without involving the public health sphere, as these fields are inherently linked. As they are inherently linked, it behooves us to approach this issue in a holistic manner. While environmental restoration efforts must be undertaken to address this imminent threat, a partnership between the environmental and public health fields is paramount.

In 2006 Ted Schettler's work, "Moving towards an Ecological View of Health: An Imperative for the Twenty First Century", was presented at a conference by The Center for Health Design and Health Care Without Harm, dispersing pertinent discourse on how the field of health care needs to adapt to the needs of communities in the face of climate-induced illness and disease. Invoking Wendell Berry, Schettler points out the failings of our current system, asking how our current medical system can adequately address the needs of the population when it has become so far removed from the health and 'whole-ness' of individuals and their habitats, emphasizing the fact that individual health cannot be reached without the health of the public and the health of the environment. Through this ecological lens, Schettler forces open the eyes of our increasingly specialized and sectionalized system of healthcare to see the necessity of systemic interventions for the holistic health approach; an ecosocial model of health.

Utilizing an ecosocial model of health and disease, a working culmination of the medical field, the public health sector, scientific advancement, and the study/reverence of the Earth's ecosystems, upon which the health of all living things rely, is the only way to best prepare communities for climate-induced health issues to come. In order to best prepare and safeguard communities for imminent health threats, systemic interventions within the public health and environmental health fields must occur. It is paramount that these fields should form a partnership to initiate adaptive management and systemic interventions in order to best serve communities.

There has never been a time in which an individual's environment did not have an impact on their health, even before our catastrophic experimentations in rampant capitalism and degradation began. The environment has always had an impact on the health of humans and, being so, lending focus to ecological restoration of health is not only a necessity, but it is also a matter of justice.

Ecological Restoration as a Matter of Environmental Justice

The best way to adapt to a changing Earth is to give back to it, to restore what we have taken away from it. Ecological restoration is not only the most environmentally and economically sustainable method of disaster risk reduction, it is also the most just. We have created unfair conditions and vulnerabilities through lack of foresight and planning, through poor land-use sprawl and urbanization, inadequate and unsuccessful efforts to alleviate poverty, and of course, ecosystem degradation (United Nations University 1995:3).

Restoring the Earth's natural buffers to environmental hazards, in addition to a public health surveillance and community monitoring, presents a promising and perhaps the best approach to preparing communities for environmental hazards and their affiliated infectious diseases and the best way to restore or achieve environmental justice.

As we know, risk is generally calculated by determining the probability of an event occurring and the consequential damage that would be caused should the event occur. Disaster risk is further calculated on the basis of three measures or factors (National Climate Assessment 2016; United Nations University 1995:5):

1. The frequency and severity of hazard events; hydrometeorological events such as floods, droughts, cyclones, avalanches, and waves of extreme temperatures.
2. The exposure of people and their assets to hazards.
3. Underlying vulnerabilities of the exposed population (such as poverty, deterioration and decline of building construction, and lacking preparations for hazards)

It is also important to differentiate between a “hazard” and a “disaster”. It bears mentioning that a disaster is not a natural occurrence, but is actually the consequential damage ensuing from a hazard event. To use New Orleans as an example, the hurricane of Hurricane Katrina was a hazard and the displacement and suffering of the residents of New Orleans post-Hurricane Katrina was a disaster. Though the frequency and severity of storms are linked to anthropogenic climate change, it does not create the inevitability of a hazard event result in disaster. Disasters occur when a hazard event, such as the hurricane, overwhelm a community’s or society’s ability to handle the damages caused by the hazard. Humans have created conditions that are changing the climate and causing an increase in the frequency and severity of hazard events, but humans also have the capacity to create and establish resiliency in communities to mitigate the effects of these events.

In the case of New Orleans, and many similar cases, there existed a huge knowledge gap in terms of resilience. The deterioration of the land's natural defenses was too great and the knowledge of ecosystems in disaster risk reduction too little. Economic developments in this area caused a loss of 4,800 km^2 of wetlands in the Mississippi Delta, the main buffer for storm surges for centuries prior (National Climate Assessment 2016:18).

While we cannot lessen the severity of a storm, we can possibly prevent, and definitely mitigate, adverse impacts a storm has on a community and, therefore, infectious disease. This is made possible through holistic analysis of a community and the underlying causal vulnerabilities that exist and addressing them in the most efficient and effective way (National Climate Assessment 2016:30).

We already know that portions of the population are unfairly burdened with the harmful effects of environmental hazards and that certain populations are more at-risk of contracting an infectious disease based on these same vulnerabilities.

We can use our knowledge of gaps in resilience knowledge from past events with our developing understanding of ecological restoration in order to mitigate the effects of environmental hazards and the impacts of infectious disease in the United States.

We need only look to the natural environment to determine the best tools for ecological restoration to provide disaster risk reduction. The first key to this ecological restoration is the proper use and preservation of lands to mitigate hazard events. In well-managed and healthy ecosystems, 1.3 million trees are able to catch 7 billion m^3 of rainwater per year, drastically reducing stormwater drainage in an ecosystem (USGCRP 2016:18).

In order to reduce rainwater runoff in urban areas, the use of natural and constructed wetlands can be employed.

While many scenarios of engineering storm surge barriers and dams have been proposed, actions have not been taken to employ them because, among other reasons, they are extremely costly and they pose a threat to biodiversity and the protection of wildlife species whose lifestyle patterns they interrupt.

Ecological restoration addresses both of these problems with win-win, no-regret solutions, as they provide multiple benefits socially, economically, and environmentally in a sustainable and cost effective manner.

Leaving out hazard mitigation and community resilience, sustainable ecosystem management provides reductions in poverty, gross domestic product, food security, biodiversity, and carbon sequestration; all factors which prove the investment worthwhile, individually, and is only further compounded by the whole (United Nations University 1995).

Mitigating the effects of floods will greatly alleviate the disease burden of waterborne and vector-borne infectious diseases. On the coasts of the United States, wetlands, tidal flats, deltas, and estuaries absorb water and decrease impacts from storm surges and tidal waves. The presence of coral reefs, sea grasses, and various coastal vegetation reduce erosion from storms and high tides, trapping sediment and organic matter, while simultaneously providing a natural buffer against saltwater intrusion (United Nations University 1995).

In coastal areas, inland river basins, and mountain areas experiencing effects of glacial melt, wetlands, wet grasslands, and peatlands are all useful restoration projects as they also contribute to flood control. These buffers allow for the quick absorption of water and the slow release of it, which reduces the speed and volume of runoff after periods of heavy rain and/or snowmelt (United Nations University 1995).

Floodplains should be restored to their natural state as they provide ecosystem services such as allowing rivers to be dynamic and absorbing flood waters. Without these ecosystem services, communities are fully exposed to devastating floods as there is no buffer space to provide floodwater retention capacity and there is no designated space left to provide a buffer between the water and the community in order to reduce the effects of flooding.

In dryland areas, there is the risk of drought. Communities should employ living fences such as shelterbelts and greenbelts to build resilience against wind erosion. Additionally, those living in drier land areas should strive to maintain vegetation cover, plant shadow crops, and nutrient-enriching plants in order to conserve soil and retain moisture to mitigate the effects of drought (United Nations University 1995).

We need to utilize ecological restoration techniques in order to build resilience in communities and mitigate the effects of hazard events. As previously discussed, changes in climatic patterns cause a change in the burden of infectious disease. In hazard events of flooding and severe storms, waterborne and vector-borne illnesses are likely to occur due to the contamination of water supply systems and the prevalence of the water itself, attracting vectors such as mosquitos.

Droughts are hazard events that are equally likely to cause an increase in infectious disease transmission as water is scarce, causing a decrease in proper sanitation and hygienic practices, leading to waterborne and foodborne diseases. This scarce water is also stored improperly, attracting vectors and, with them, vector-borne diseases.

As it has already been determined that portions of the population are more at-risk of suffering the effects of hazard events and increased rates of waterborne, foodborne, and vector-borne infectious diseases, the need for ecological restoration could not be any clearer. To give back to the Earth, to the communities who are already suffering, and those who are increasingly vulnerable as the effects of climate change continue to develop.

The risk is too great as hazard events become more probable and the consequences of their occurrence become unbearable to the human population.

Conclusion

The sections of this thesis have been specifically chosen to clarify the importance of the relationship between climate change and infectious disease in the United States. This has been done through the analysis of infectious disease history and specific examples in the United States and where we can see infectious disease outbreak, as predicted by climate change data. While this is a useful endeavor in and of itself, this thesis further serves to illuminate the importance of ecological restoration and public health preparation to best prepare communities of the United States for these imminent threats. As the time for completely reversing the damage humans have caused to the earth as passed, it is now important to shift our collective focus to adaptation, preparation, and mitigation of the inevitable.

The relationship between environmental health and human health is evident and the relationship between climate change and infectious disease patterns are undeniable. As climate change continues to transform the natural processes of our natural environment, climate-related illnesses and infectious disease will continue to increase. This increase occurs due to breakdowns in systems, for example a hazard event such as a severe storm can cause flooding. This flooding can overwhelm water treatment facilities, causing the local water supply to become inundated with all manners of toxic waste, including fecal matter. Strain, of any kind, on the water resources of an area can severely threaten the public water supply, causing waterborne infectious diseases such as cholera and cryptosporidiosis.

When water becomes scarce, the first instinct of the public is to store water for future use. If this water is not stored properly, it can become unsanitary very quickly and provide a comfortable habitat for various vectors carrying vector-borne diseases such as several species of mosquitos carrying Zika, Malaria, and West Nile virus. If the water supply becomes so threatened that it is a scarce resource, public health will decline drastically due to unsanitary and unhygienic conditions. This can cause food-borne illnesses such as Salmonella, *E.coli*, and the Norovirus.

Hazard events can quickly cause disaster situations in which entire communities of the population are placed at extreme risk of death and illness. Preparing for these events and attempting to mitigate the impacts of infectious disease is no longer just good common sense, it is also a matter of justice.

It is becoming increasingly evident and problematic that specific portions of the population are unfairly vulnerable to infectious disease. A person living in poor conditions, as indicated by the social determinants of health, is more likely to be ill than their wealthier counterparts. The socioeconomically disadvantaged populations suffers from limited access to adequate medical care and attention than those in wealthier neighborhoods. They also have limited access to nutrition, healthy and green spaces, and live in areas in which severe air pollution is a daily experience.

If we take a deeper look into this issue, we can see that the portions of the population in the United States that are the most at-risk are communities of color, indigenous communities, refugee populations, and displaced individuals from within the United States. Within these portions of the population, there is even further vulnerability for infants, children under the age of five, pregnant women, the elderly, and the chronically ill. When you figure that most of the socioeconomically disadvantaged population is suffering from chronic illnesses such as asthma and diabetes, discussed at length previously, the damning connection is abundantly clear-- the poor and communities of color are shouldering the burden of infectious disease in the United States.

The wretchedness of this situation is further exacerbated by the recognition that these populations are recipients of a problem not of their own making. They inherit the bulk of the negative karma their wealthier counterparts have created. Those who have contributed the least to this problem are suffering the most. While climate-related illness and infectious disease will certainly not discriminate who will fall ill, there are portions of the population more vulnerable and more at-risk to pathogen and vector exposure than ever before. This is not a simple issue of public health, but rather a complex, holistic issue of environmental public health justice.

The only way to mitigate the effects of the inevitable is to prepare and build resiliency to the imminent impacts of increased hazard events and infectious disease by addressing the health of the public and the health of the environment, simultaneously. In this way, the United States has the opportunity and knowledge to prepare for the inevitable in the most cost-efficient, effective, and just way possible.

While it will be necessary to change policy on a National and International level to decrease emissions, it is important that we also respond on a local level to provide the most good to those who are already vulnerable to climate-induced illness. Those with the most wealth have always held the greatest amount of power in our society. The poor have always been the first to suffer. Increased rates of infectious disease will spare no man, but there are those who have been unfairly burdened by vulnerabilities, putting them at even greater risk than their wealthier counterparts.

While changing policy on an International level would decrease emissions on a far wider scale with greater speed, we cannot simply wait for this to happen, we do not have the time to waste with baited breath. We need to act now and affect change from the local level up towards the International level by setting an example, by preparing our communities as best as we can, to mitigate the effects of inevitable infectious disease by giving back to the Earth, restoring the natural ecology.

Through iterative adaptive and mitigational management principles, the United States can work with communities on a local level to build resiliency against these imminent threats. While we have reached a point of no return in terms of preventing climate-related illness, we are able to mitigate the effects. Focusing on this possibility will be to the advantage of the United States and set a global example of holistic resiliency and adaptive capacity of not only ecological restoration interventions, but also public health response.

In this way, the United States can correct heinous examples of environmental injustice and, perhaps, alter the karmic return we have so justly brought upon our consumption-obsessed homeland.

SAMPLE FACT SHEET, FOR PUBLIC USE

Public Health Benefits of Ecological Restoration

In order to mitigate the negative public health effects of climate change and hazard events in communities it is necessary to give back to the Earth and restore the ecology of the land. As climate and weather patterns continue to change, increasing the frequency and severity of storms and hazard events, communities are exposed to the destruction and negative public health consequences. Restoring the land is the most cost effective and efficient way to protect communities.

Methods of Ecological Restoration:

- Improve biodiversity conservation by re-planting and conserving native sea grasses and coastal vegetation to control sediment.
    - Coral reefs, sand dunes, sea grasses, peatlands, wet grasslands, mangroves, and saltmarshes (National Climate Assessment 2015:19).
- Natural and constructed wetlands to aid in storm surge relief and reducing the volume of rainwater runoff.
- Restore floodplains to increase flood retention capacity.
- In drier land areas, maintain vegetation cover with nutrient-enriching plants and shadow crops to conserve soil and retain moisture.
- Utilize shelterbelts and greenbelts to protect communities from wind erosion and potential sandstorms.

Public Health Benefits of Ecological Restoration

- Natural barriers and buffers will decrease the severity of floods in coastal communities.
    - Protects damage to infrastructure such as wastewater treatment plants, decreasing the possibility of contaminated water entering public water supply.
    - Limits exposure of community to waterborne diseases such as cryptosporidiosis and cholera.
- Efforts limit exposure to polluted and contaminated water.
- Decreases disease burden due to evacuations and emergency shelters.
- Less free-standing water = less vectors.

(Source: National Climate Assessment 2016, USGCRP 2016)

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