Maryland Climate and Health Profile Report

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Maryland Department of Health and Mental Hygiene

ACKNOWLEDGEMENTS

MARYLAND DEPARTMENT OF HEALTH AND MENTAL HYGIENE

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ACRONYMS

95% CI: 95% Confidence Interval
ACS: American Community Survey
DHMH: Department of Health and Mental Hygiene
BRACE: Building Resilience Against Climate Effects
BRFSS: Behavioral Risk Factor Surveillance System
CDC: Centers for Disease Control and Prevention
ENSO: El Niño Southern Oscillation
EPHT: Environmental Public Health Tracking
EPT_{90}: Extreme Precipitation Threshold 90^{th} percentile
ER: Emergency Room
ETT_{95}: Extreme Heat Threshold 95^{th} percentile
GEE: Generalized Estimating Equations
HSCRC: Health Services Cost Review Commission
ICD: International Classification of Diseases
IPCC: Intergovernmental Panel on Climate Change
IRR: Incident Rate Ratio
MI: Myocardial Infarction
OR: Odds Ratio
PM: Particulate Matter
PRCP: Daily maximum precipitation
RCP: Representative Concentration Pathway
SES: Socioeconomic Status
TMAX: Daily maximum temperature
WNV: West Nile Virus
WRF: Weather Research and Forecasting model
Yrs: Years
VSA: Vital Statistics Administration

EXECUTIVE SUMMARY

In 2011, Maryland released its *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase II: Building societal, economic, and ecological resilience*. The first recommendation of that report was for the State to: ***Conduct vulnerability assessments to gain a better understanding of risks and inform preventative responses.***

In response, the Maryland Department of Health and Mental Hygiene (DHMH) and the University of Maryland School of Public Health have developed the Maryland Climate and Health Profile. This profile is based on and developed in conjunction with the DHMH Maryland Public Health Strategy for Climate Change project, funded by the U.S. Centers for Disease Control and Prevention (CDC) as part of its Climate-Ready States and Cities Initiative. This Climate and Health Profile Report summarizes results of a collaborative effort by DHMH, local health departments, and academic institutions utilizing the CDC's Building Resilience Against Climate Effects (BRACE) framework to use climate models and health data to predict how anticipated climate effects might affect public health in Maryland, as a first step towards development of interventions and strategies to detect and prevent those health impacts.

The Climate and Health Profile examines anticipated public health impacts of climate effects on foodborne and waterborne diseases, cardiorespiratory conditions, motor vehicle accidents, and vector-borne diseases. Part of the goal of the report is to describe the anticipated impacts; another is to identify data gaps and areas where additional data or research might be helpful. In addition to extreme events, climate change can lead to increased frequency of coastal flooding, reduced air quality, alteration in plant life cycles, drought related forest fires, as well as changes in geographic patterns of vector-borne diseases; all of which can negatively impact human health. These disruptions can significantly exacerbate health problems, such as increasing respiratory and cardiovascular disease, injuries, and premature deaths. Moreover, changes in exposure pathways and locations where food and waterborne illnesses are contracted contribute to health concerns.

An increasing body of literature suggests that the frequency, intensity, and duration of extreme events are on the rise, and will continue this trend in the foreseeable future in response to our changing climate. While some of the public health impacts are inferred from the present body of literature, to date limited research is available on how the frequency of extreme heat and precipitation events may influence health risks among the general public in Maryland. The Climate and Health Profile Report identifies selected adverse health outcomes that are projected to be exacerbated among Marylanders as well as illustrates the magnitude of the effects that are derived using Maryland specific health data.

This report further underscores the need to engage stakeholders, particularly local communities, and enhance active partnerships involving local and state governmental agencies, academia, and businesses to devise mitigation and community-specific adaptation strategies that will effectively minimize such burdens among Marylanders.

KEY FINDINGS

Health outcomes examined in this report include: risk of *Salmonella* and *Campylobacter* infection, hospitalization for asthma and heart attack, and motor vehicle accidents. These health outcomes are representative examples, rather than a comprehensive list of adverse health outcomes, that will be experienced by Marylanders. Key findings from this report include:

- ***In Maryland, the occurrence of summertime extreme heat events more than doubled during the 1980s, 1990s, and 2000s compared to the 1960s and 1970s. The seasonal frequency of extreme precipitation events remained relatively stable over the same time period.***

- ***Both extreme heat and extreme precipitation events significantly increase the risk of Salmonella infections in Maryland. The risk of Campylobacter infections increased in response to extreme precipitation events.***

- ***The increased risk for Salmonella infections related to extreme heat and precipitation events is higher in coastal communities surrounding the Chesapeake Bay and Eastern Shore regions of Maryland, compared with inland communities.***

- ***During 2000-2012, exposure to summertime extreme heat events significantly increased the risk of hospitalization for heart attack in Maryland. The extreme heat-related risk was considerably higher among non-Hispanic blacks compared to non-Hispanic whites.***

- ***During 2000-2012, exposure to summertime extreme heat and precipitation events significantly increased the risk of hospitalization for asthma across Maryland. The extreme heat related risk of hospitalization for asthma was highest among non-Hispanic whites and 5-17 year olds.***

- ***Exposure to extreme precipitation events significantly increased the risk of motor vehicle accidents, particularly during the fall and summer months.***

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of Salmonella infection in Maryland. The magnitude of the increase in Salmonella infection rate is projected to be relatively small.***

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of hospitalization for heart attack. The magnitude of the increase in heart attack hospitalization rate is projected to be moderate in Maryland.***

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of hospitalization for asthma in Maryland. The magnitude of the increase in asthma hospitalization rate is projected to be large.***

- ***The rise in disease burden related to the increases in the frequency of summertime extreme heat events is projected to vary considerably across the 24 counties in Maryland, and may differ from the statewide outlook.***

- ***Because motor vehicle accidents are a major regional and statewide cause of injury-related emergency department visits and hospitalizations, the health and cost impacts of increasing extreme weather events on motor vehicle accidents may be significant.***

The impacts of climate change on human health vary and depend upon, among other factors, an individual's sensitivity, preexisting conditions, other co-exposures, and an individual's capacity to adapt. The vulnerability assessment described in this report show that the health burdens related to extreme events are not uniformly distributed across the State of Maryland. Adaptation strategies designed to build vibrant and resilient communities need to take such differential burden into account.

CHAPTER 1: INTRODUCTION

The impacts of climate change on public health are significant and complex. Whether it is more frequent and intense heat waves, greater coastal flooding, changes in mosquito habitat, or longer pollen seasons, climate change is affecting public health in more ways than we can imagine.

This report, the result of the Maryland Public Health Strategy for Climate Change project funded by the U.S. Centers for Disease Control and Prevention's (CDC)Climate-Ready Cities and States Initiative, presents an assessment of how climate change is affecting or will likely affect the health of Marylanders. The report further identifies specific vulnerable communities in the state and specific populations that might experience a disproportionate burden of disease. The report is intended for policy makers, planners, public health officials, preparedness personnel, health care providers, and anyone with an interest in the relationship between our changing climate and public health. It represents the public health community's best estimates of current and future health impacts, based on a combination of empirical evidence and modeled results of the relationship between attributes of changing climate (frequency of extreme events)and health in Maryland.

Maryland's Public Health Strategy for Climate Change is one part of the State's comprehensive Climate Action Plan, which includes mitigation strategies to reduce greenhouse gases that contribute to climate change, and adaptation strategies to help Maryland prepare for climate change impacts that are occurring or are likely to occur. ***Phase-I*** of the adaptation strategy focuses on Maryland's particular vulnerability to sea-level rise and coastal storms. ***Phase-II*** of the adaptation strategy is a comprehensive plan for societal, economic, and ecological resilience, including anticipated human health impacts. Chapter 1 of the adaptation strategy report, which addresses human health, has three key points:

- ***Climate change will likely cause increases in heat stress, reduced air and water quality, and shifts in vector-borne disease risk (Figure 1). The impacts of climate change on human health will vary and depend on, among other factors, an individual's sensitivity and exposure to a given threat and the capacity to adapt.***

- ***Reducing impact should focus on integrating climate effects into decisions affecting human health and increasing preventative measures. Funding and planning efforts should be informed by the projected interactions between human health impacts and the existing vulnerabilities of populations. The co-benefits of other management actions that are not exclusive to the health of a community (e.g., increasing urban canopy) are emphasized.***

▶ ***Preventative actions are dependent on Maryland's capacity to track current disease patterns and project future threats to human health. Given the vulnerability of potential impacts to human health statewide, there is a vast need to collect and make health information available at a high spatial resolution.***[1]

The Climate and Health Profile is the result of a four-year effort by the Maryland Department of Health and Mental Hygiene (DHMH) and the University of Maryland School of Public Health and is based on the BRACE (*Building Resilience Against Climate Effects*, Figure 1) framework developed by the CDC. It represents the first two steps in the BRACE framework, which is a systematic evaluation of potential health impacts, through the following steps:

1. Forecast relevant climate impacts, using appropriately scaled (for time and place) models;
2. Project the anticipated disease burden, based on a detailed assessment of the population's baseline health and the anticipated climatic changes;
3. Develop and test interventions to prevent or lessen the anticipated health impacts;
4. Use the interventions that have proven to be successful in the state's adaptation plan; and
5. Continue to evaluate and improve both the surveillance and interventions.

The Maryland Climate and Health Profile provides a summary of likely health risks related to anticipated changes in Maryland's climate. It is not a comprehensive evaluation of all health outcomes that may be impacted by our changing climate, but rather, examples of how such impacts are differently felt across geographic areas, population subgroups, and time. This information is designed to guide adaptation strategies at the local and State level. A part of that strategy involves the public health response to climate change, which focuses on specific assessment, surveillance activities, prevention and harm reduction strategies, and outreach activities related to the public health impacts of climate change.

The remainder of the Climate and Health Profile is structured as follows. Chapter 2 is a brief description of the methods used to create the Climate and Health Profile. Chapter 3 provides a summary of results including i) Baseline Health Assessments, which were prepared from a standardized set of health, economic, and sociodemographic indicators for Maryland; ii) observed frequencies of extreme heat and precipitation events in Maryland during the 1960-2012 period; iii) relationship between extreme events and selected diseases in Maryland during 2000-2012; iv) projection of extreme heat events in Maryland in 2040; and v) projections for selected diseases in Maryland as a result of these extreme heat events in 2040. Chapter 4 provides the summary of county level results that were provided to each of the four participating counties. Chapter 5 is a brief summary of the uncertainties, and Chapter 6 provides conclusions. Finally, details regarding methods and results described in Chapter 2 are presented in the Appendix section.

Much of the work in this report has been done with input from four jurisdictions that served as

Figure 1. Climate drivers and their potential health consequences across Maryland.[1]

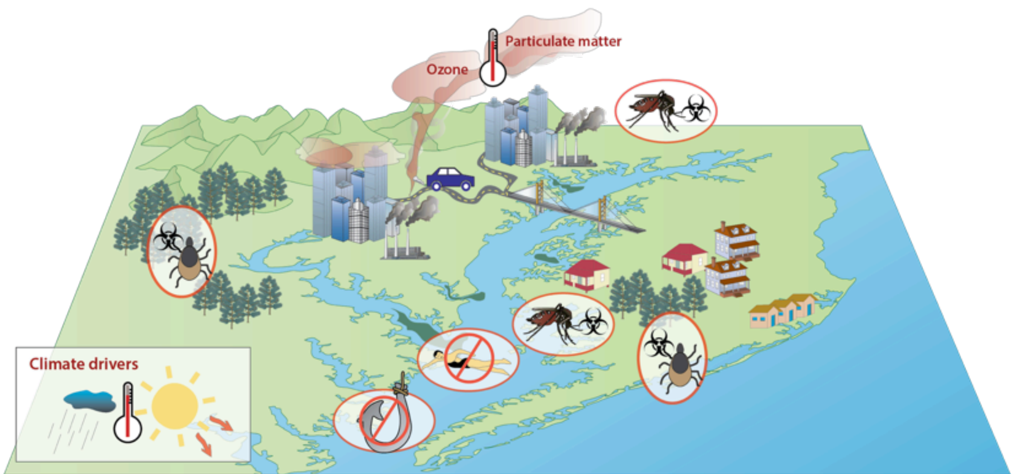
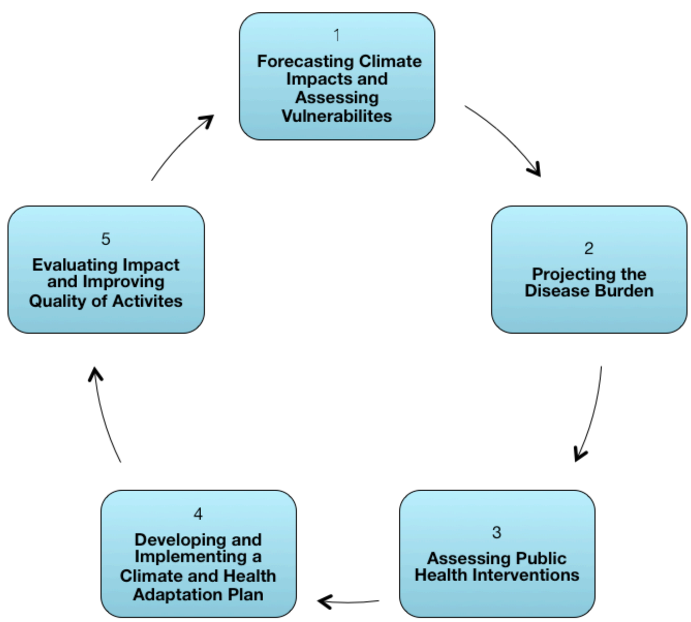


Figure 1.1: Climate drivers, such as temperature and precipitation, influence many health issues. Health issues are likely to change or become exacerbated. Among those health concerns occurring across the State are water contamination or harmful algal blooms , which prevent swimming and fishing . Increases in temperature and changes to precipitation patterns are likely to influence air quality , heat stress, and vector-borne diseases across the State.

case studies: Baltimore City, Prince George's County, Washington County, and Wicomico County. They were invited to participate based on their geographic location, as well as their varying degrees of activities related to climate change. By intention, they were not all actively engaged in health-related climate change activities; part of the goal of the project was to get a realistic picture of how different communities might respond to information presented in the BRACE process.

Figure 2. CDC Building Resilience Against Climate Effects (BRACE) Framework.

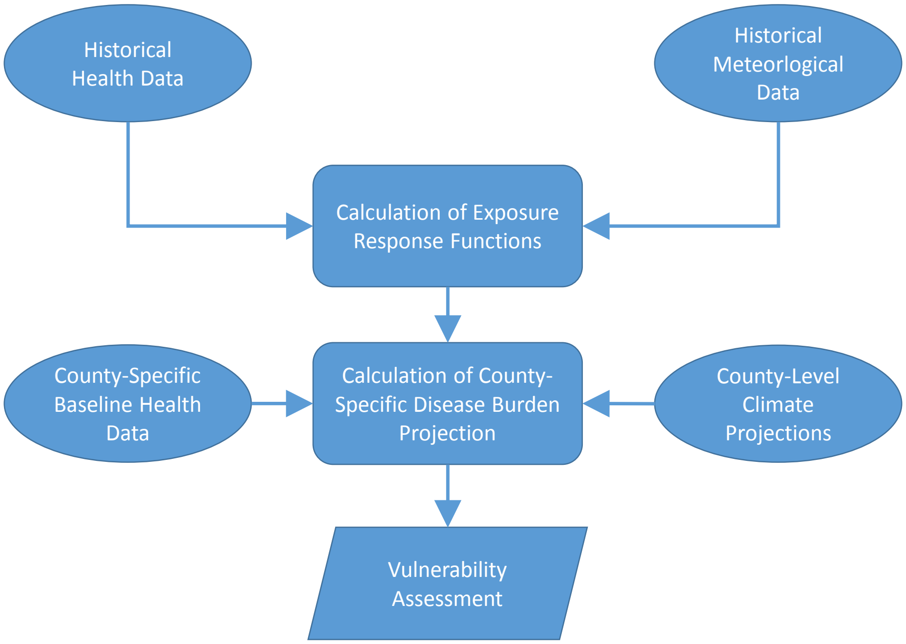


The authors wish to acknowledge the significant contributions of these four communities and their health departments to the work in this report. The four communities are continuing to participate in the BRACE framework by testing interventions for specific health impacts, which will be the subject of subsequent reports. This report does not represent the last word on the health impacts of climate change in Maryland; rather, it represents the best estimate of some of those impacts at this point in time. It is anticipated that these estimates will be refined over time, so that appropriate responses can be formulated and implemented.

CHAPTER 2: METHODS

This section provides a summary of methods used to create the Climate and Health Profile report. These methods are described in detail in Appendix 1. The methods are shown pictorially in Figure 3, below. In summary, meteorological data from 1960-1989 (a 30-year baseline) was used to calculate location and calendar day specific thresholds for maximum temperature (95^{th} percentile), and total precipitation (90^{th} percentile). The daily maximum temperature and total precipitation values were compared to their respective location and calendar day specific thresholds to identify extreme heat and extreme precipitation events. These extreme event data were combined with the health data to calculate risk estimates (referred as exposure-response functions) that describes the relationship between extreme event and adverse health outcomes for each of the counties in Maryland. These exposure-response functions were then combined with climate projections and population projections to derive disease burden in 2040.

Figure 3. Schematic of Climate and Health Profile Methods



BASELINE HEALTH ASSESSMENTS

The first part of the BRACE framework calls for an assessment of the baseline health of the population. The DHMH Environmental Public Health Tracking Project (EPHT) developed a baseline health assessment across all of Maryland and four pilot counties (selected for geographic diversity) in Maryland to characterize the overall health during a baseline time period spanning 2000 (Figure 4) to 2010 (Figure 5). Demographic and socioeconomic factors, major health indicators, and behavioral risk factors were incorporated into this baseline health assessment. By using a uniform set of indicators as a part of the baseline assessment, it was possible to compare similarities and/or differences between the counties (Chapter 4) prior to the implementation of the BRACE framework, and to compare the impacts of climate change projections on a comparable set of health outcomes.

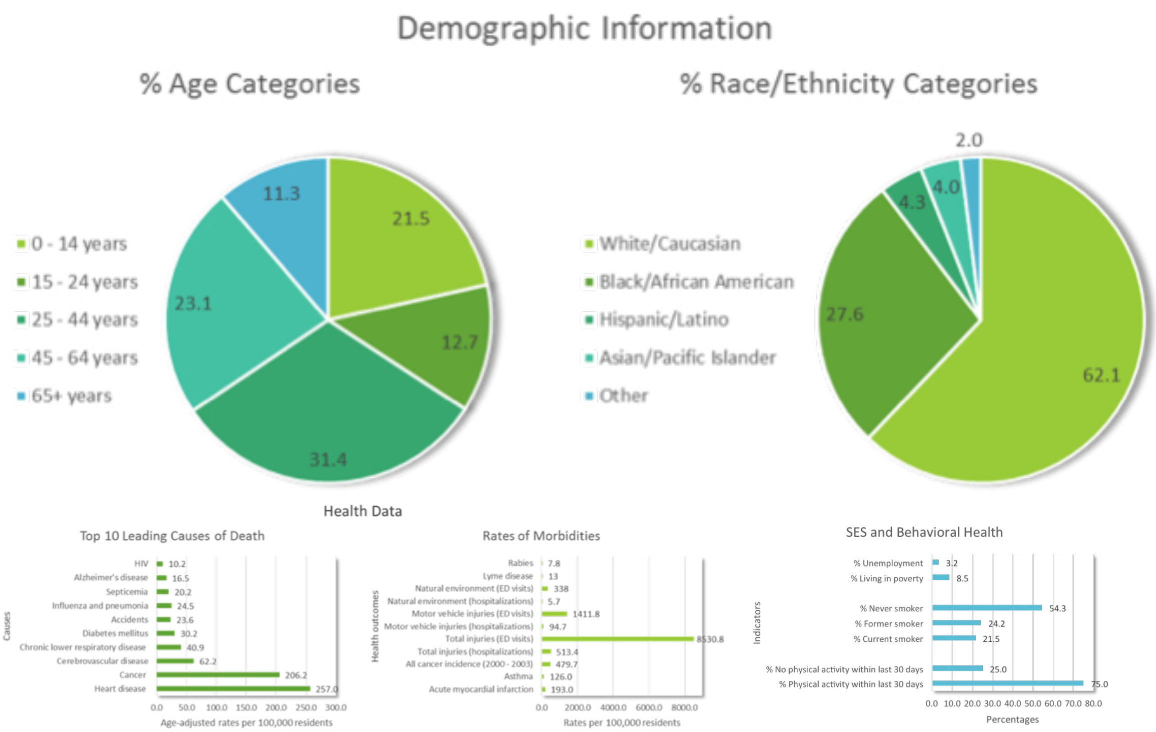
A detailed discussion of data sources, lists of demographic and socioeconomic indicators included, and analytical methods utilized for the baseline health assessment is provided in Appendix 1.

Summary of Results

Given the wide geographic spread and diversity of the four pilot jurisdictions, there were significant variations with respect to the demographic and socioeconomic indicators that reflect population migration and economic change over time. Regarding the health indicators, some of the more interesting trends include:

- ***Universal improvement in general health as reflected in decreased all-cause mortality rates in Maryland and all four jurisdictions over the 10-year period (2000 to 2010);***

Figure 4. Demographic information for Maryland's population, in 2000.



- ***An increase in asthma hospital discharges between 2000 and 2010 for the State and all four jurisdictions;***

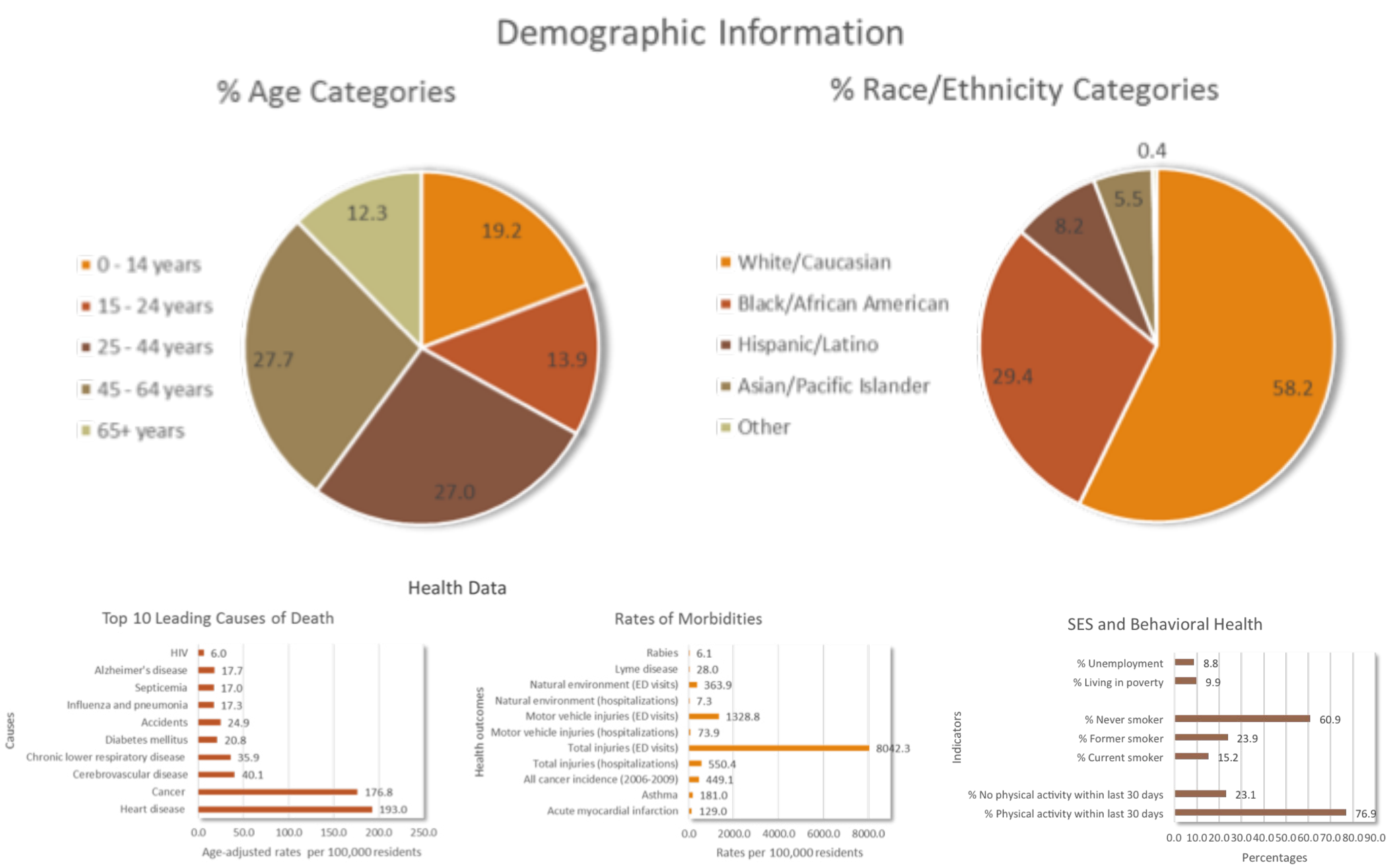
- ***An increase in hospitalization rates for all injuries over the decade (2000 to 2010) of data collection for all four jurisdictions;***

- ***An increase in rates of Lyme disease in Maryland and three of the four jurisdictions (Baltimore City, Prince George's, and Washington Counties) for which these data were available.***

- ***Motor vehicle accidents account for a significant fraction of all injury-related emergency department visits and hospitalizations in every jurisdiction and statewide.***

These data, described in detail for the four jurisdictions in Chapter 4, were presented to the respective jurisdictions as a standardized template of demographic, socioeconomic, and health data for local health officials, and also in part to help inform their respective intervention strategies for addressing future disease burden in their areas.

Figure 5. Demographic information for Maryland's population, in 2010.



FREQUENCY OF EXTREME EVENTS IN MARYLAND (1960-2012)

Climate refers to an aggregate pattern of weather events (e.g., temperature, precipitation, snowfall, snow cover, humidity, dryness, blizzards, tornadoes, etc.). These may include long-term averages, extremes, timing, as well as spatial distribution of these events. Climate change refers to deviation from these long-term trends. In order to understand how Maryland's climate is changing, we focused on two elements: the frequency of extreme heat, and of precipitation days. Data sources and analytical methods used to calculate these metrics are described in further detail in Appendix 1.

The results show that:

- ***The occurrence of summertime extreme heat events more than doubled during the 1980s, 1990s, and 2000s compared with the 1960s and 1970s.***

- ***The seasonal frequency of extreme precipitation events remained relatively stable in Maryland over the past 50 years (since 1960).***

- ***The spatial distribution of extreme heat and precipitation events varied across all of the 24 counties in Maryland***.

CLIMATE PROJECTIONS

Projections for the frequency of extreme heat events at the county level across Maryland were obtained from the U.S. Centers for Disease Control National Environmental Public Health Tracking Program.[2] These projections are based on two scenarios, low emissions with a service economy (B1) and high emissions with regional growth (A2), as outlined by the United Nations International Panel on Climate Change (IPCC). Additional projection of extreme heat events were done based on the modeled results from the Climate extension of the Weather Research and Forecasting model (CWRF)[3] as described in Appendix 1.

Notable findings from the climate projections for Maryland were:

- ***The frequency of extreme heat events in Maryland will likely continue to increase through 2040 (Table 18).***

- ***The frequency of extreme precipitation events will likely remain relatively stable through 2040 (Table 18).***

- ***The spatial pattern of extreme heat events in 2040 based on the Climate extension of the Weather Research and Forecasting model (CWRF) is most closely aligned with the observed extreme heat events during 2000-2010 (Figure 18).***

RELATIONSHIP BETWEEN OBSERVED EXTREME EVENTS AND SELECTED DISEASE BURDEN IN MARYLAND (2000-2012)

The BRACE Framework calls for a vulnerability assessment based on climate projections and associated risk for specific health outcomes. The relationships between changing climate, extreme weather events, and specific health outcomes are complex and based on many factors. The underlying mechanism for the association between climatic factors and diverse health outcomes is starting to emerge. That said, however, epidemiologic studies have shown that increases in temperature are associated with an elevated risk of heat-related health effects, such as heat stroke. For such outcomes, the actual risk (exposure-response function) depends upon the age, sex, race, and underlying population health that varies by location.

In addition, according to the Intergovernmental Panel on Climate Change (IPCC), extreme weather events are very likely to increase in frequency, intensity, and duration, which will vary relative to the time of year (season) and geographic location,[4] so the resulting risk will vary by geographical areas. For these reasons, state and county level risk estimates were developed for each health outcome considered, prior to their use in disease projections.

Motor Vehicle Accidents

In 2012, approximately 2.4 million people were injured in motor vehicle collisions across the United States, with 34,000 fatalities observed during this time period.[5] In Maryland, motor vehicle accidents were consistently the 12th leading cause of mortality for the years 2010 through 2013.[6] During this time period, there were approximately 450 fatal crashes each year, and the number of crashes resulting in injury ranged from 30,513 in 2010 to 29,213 in 2013.[7] Detailed methods for data acquisition, analysis, and results are discussed in Appendix 1.

Notable findings based on 2000-2012 data for Maryland include:

- ***Exposure to extreme precipitation events resulted in a 23% increase in risk of motor vehicle accident.***
- ***The risk of extreme precipitation related motor vehicle accidents were highest during the fall season.***
- ***Motor vehicle accidents related to extreme precipitation were 46% more likely on roads with defects or obstructions.***
- ***Motor vehicle accidents account for a significant fraction of all injury-related emergency department visits and hospitalizations in every jurisdiction and statewide.***

Generally, extreme heat showed minor associations or even marginally negative associations with motor vehicle accidents in that fewer accidents were observed in relation to extreme heat, particularly during the fall and winter months. Examining across different road conditions, the relationship with extreme heat was inconsistent.

Cardiovascular Disease

Myocardial infarction (heart attack) occurs when the cardiac muscle gets insufficient blood flow and/or oxygen.[8,9] About 735,000 people in the U.S. suffer heart attacks each year but rates and mortality of a heart attack differ by demographic characteristics.[10] More men than women experience and die from heart attacks, and the new occurrence of a heart attack increases as a person becomes older. The average age of a first heart attack is 65 years for men and 72 years for women.[10]

There are a number of hypotheses regarding the possible mechanism(s) by which increasing ambient outdoor temperature may increase the risk of a heart attack, including changes in blood viscosity ("thickness"), heart rate, or an effect on so-called "bad" cholesterol levels.[11,12] Other suggested mechanisms, potentially more important, are the interactions between air temperature and air quality. As temperatures rise, especially at the extremes, air quality often worsens, contributing to the risk of cardiac events.[13,14] There have been a few studies on the exposure to extreme heat and risk of a heart attack, but the findings from these studies have been mostly varying and results are different depending on the location of residence.[15] In a changing climate, extreme weather events are expected to become more frequent and intense. Public health practitioners need information on how these changes will alter the disease dynamics in the future. In addition, examination of risk across population subgroups is also of particular interest, as identifying those most vulnerable to the effects of extreme heat is necessary to target interventions.

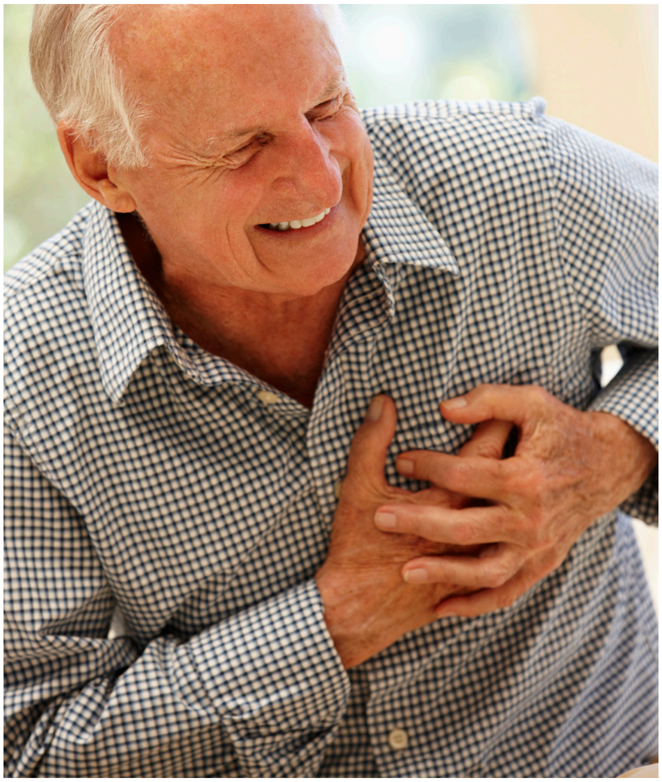
Details regarding methods as well as results are provided in Appendix 1.

In summary, results for Maryland based on 2000-2012 hospitalization data show that:

- ***Exposure to extreme heat event increased the risk of hospitalization for heart attack by 11% during summer months (Table 22).***

- ***The increases in extreme heat-related risk were considerably higher among non-Hispanic blacks (27%) compared to non-Hispanic whites (9%) (Table 22).***

- ***The increase in risk of hospitalization associated with exposure to extreme heat events during summer time was highest among residents of Baltimore City (43%) (Table 2).***



Respiratory Disease

Asthma is a complex chronic lung disease, driven by many factors. It is characterized by inflammation of the airways, reversible airway constriction, and excess mucus secretion.[16] This narrowing of the airway results in reduced airflow that may cause symptoms of wheezing, coughing, tightness of the chest, and difficulty breathing.[16] Asthma attacks are triggered by exposure to allergens (i.e., mold, dander, dust mites, and pollen), tobacco smoke, occupational hazards, and air pollution.[17–22]

There are a number of possible explanations for why asthma is likely to increase with more severe climate, such as increases in outdoor air pollution in periods of extreme heat, increasing allergens, and thunderstorm-related impact. Several studies have reported an association between increasing mean or maximum temperature and frequency of emergency room visits for asthma.[23–28] Furthermore, associations between asthma attacks and thunderstorms have been highlighted in multiple locales.[29–32] However, there is limited research on how the frequency of extreme heat and precipitation events may influence the risk of hospitalization from asthma.

Detailed results regarding exposure to extreme heat and precipitation events and its impact on hospitalization for asthma is provided in Appendix 1.

In summary, results based on hospitalization data for Maryland during 2000-2012 show that:

- ***Summertime extreme heat and precipitation events increased the risk of hospitalization for asthma in Maryland by 22% and 11%, respectively (Table 24).***
- ***In Maryland, the extreme heat related risk of hospitalization was higher for non-Hispanic whites (33%) compared to non-Hispanic blacks (20%). Such increase in risk was not observed among Hispanics (Table 24).***
- ***In Maryland, the extreme heat related risk of hospitalization was most pronounced in the 5-17 year olds (36%) followed by 18-64 year olds (28%) (Table 24).***

Food and Water Borne Illnesses - Salmonellosis

Salmonella infection or salmonellosis is a bacterial disease that occurs mainly in the gut (intestinal tract). *Salmonella* is the term used to define over 2,300 different groups of bacteria that cause gastroenteritis, enteric fever, and other illnesses. People become infected with *Salmonella* mostly through tainted water or foods, mainly via meat, poultry, and eggs.[33] The symptoms of *Salmonella* infections include diarrhea, fever, and abdominal cramps. These infections often last 4 to 7 days and most people may recover without medical treatment.[34] However, more serious symptoms such as septic infection in people with weak immune systems will need medical treatment.[34] *Salmonella* infection causes likely 1.2 million cases of acute gastroenteritis, including 23,000 hospitalizations and 450 deaths, in the United States each year.[35]

Prior studies have looked at how changes in weather events affect the number of people who contract *Salmonella* infections.[36,37] *Salmonella* infections are known to grow rapidly during warmer months and heavy rainfall. These changes in weather allow for easier transmission into surface water (streams, rivers, lakes, wetlands, and the ocean) and food crops.[36–41] Global climate change is likely to raise both the number of days that are hotter and wetter than normal.[42] Also, coastal areas may be differentially impacted by a rise in *Salmonella* infections because of increased risk of flooding that can contaminate drinking water supplies.[43]

Detailed analysis and results for *Salmonella* infections during 2002-2012 is provided in Appendix 1.

Notable findings include

- ***Exposures to extreme heat and precipitation events significantly increased the risk of Salmonella infections in the State of Maryland (Table 26).***

- ***This increased risk is stronger in coastal communities surrounding the Chesapeake Bay and Eastern Shore of Maryland (Table 26).***

Food and Water Borne Illnesses - Campylobacteriosis

There are several pathways by which a person can contract *Campylobacter* infections, including consumption of undercooked poultry[44] or unpasteurized milk[45], exposure to contaminated water[46], and contact with animals, livestock, and feces.[47–49] *Campylobacter* infections have also been identified as a risk factor for the development of functional gastrointestinal disorders, inflammatory bowel disease, celiac disease, reactive arthritis, and Guillain-Barré syndrome.[50] The symptoms of *Campylobacter* infections usually last between 3 to 6 days and include diarrhea, abdominal pain, fever, headache, nausea, and/or vomiting.[51] Approximately 1 million people across the U.S. are infected with *Campylobacter* annually.[35] Climatic factors, such as extreme weather events, may affect a pathogen's ability to grow, persist, and be transmitted through a number of exposure pathways.[52,53] Several studies have reported associations with *Campylobacter* infections and weather related factors including maximum temperature, rainfall, and relative humidity.[54–56] Particularly noteworthy are studies that have suggested a positive association between average weekly temperature and campylobacteriosis risk.[52,56-61] Global climate change is likely to increase both the number of days that are hotter and wetter than normal,[42] which may lead to increased risk of *Campylobacter* infection.

Detailed methods and results for the *Campylobacter* infections related to extreme events in Maryland during 2002-2012 are provided in Appendix 1. Notable findings include:

- ***Extreme heat event is not associated with Campylobacter infections in Maryland (Table 28).***

- ***Extreme precipitation is associated with increased risk of Campylobacter infections only in the coastal areas of Maryland (Table 28).***

PROJECTION OF DISEASE BURDEN IN MARYLAND

This section describes the projection of future disease burden (step 2 of the BRACE framework) for the entire state of Maryland. The purpose of this disease burden projection is to inform Maryland's public health agencies about the key vulnerabilities and risks that may arise in the future in response to Maryland's changing climate. For example, understanding the future disease burden among vulnerable populations - such as children, the elderly, persons living in poverty, persons residing near coastal communities, or persons living with pre-existing health conditions - can inform more targeted adaptation and mitigation strategies to minimize the risks that may adversely impact such vulnerable populations.[62-64] The outcomes of this section should not be considered as an end product. Rather, this should be an ongoing process that will need to be continually updated to reflect the improvements in scientific understandings related to the disease dynamics, mathematical modeling, as well as availability of more health data covering a longer time frame and finer geographical resolution.

The disease burden projection relies on the risk estimates (exposure-response functions) derived for the entire state (presented earlier in this chapter), disease rate at present (2010), projected increase in number of extreme events in the future (2040), as well as projected population in the future (2040). Details regarding methodology as well as detailed results are provided in Appendix 1. The year 2040 was chosen because that was the last year for which the county and state level population projection was available from the Maryland Department of Planning.

For this report, the disease projection was done for summer months only, rather than the entire year. Likewise the projection focused on extreme heat events only using the CWRF projections. This projection relies on the high-end scenario (Representative Concentration Pathway or RCP 8.5). Since the risk of *Campylobacter* infection was not related to extreme heat events, the projections did not include *Campylobacter* infection.

Ranking of Disease Burden Projection

The projected disease burdens have inherent uncertainties associated with the climate models and emission scenarios, as well as background variability in disease rate and uncertainties in exposure-response functions that are related to surveillance of outcome measures, exposure assessment methods, and statistical approaches. Recognizing this, the projected disease burden for Maryland is expressed using a ranking method (Small, Moderate, Large) rather than in terms of absolute numbers. The rankings are based on background variability in disease rate in Maryland observed between 2000 and 2012. The 2000-2012 period is relevant because the exposure-response functions used for disease projection were derived using empirical data from this time. For the 2000-2012 period, the rate of hospitalization for asthma during summer months varied by 56.8% (lowest: 21.3 per 100,000 in 2002 to highest: 33.4 per 100,000 in 2009). Likewise, the rate of hospitalization for heart attack varied by 39% during the same period. Therefore, we assumed the natural variability in disease rate to be approximately 50%. We used this variability for ranking the projected disease burden in 2040:

Small: If the increase in projected disease burden in 2040 is less than 50% of the 2010 baseline disease rate.

Moderate: If the increase in projected disease burden in 2040 is between 50 to 100% of the 2010 baseline disease rate.

Large: If the increase in projected disease burden in 2040 is greater than 100% of the 2010 baseline disease rate.

Summary of Results:

Increases in the frequency of extreme heat events into the future (year 2040) will lead to an additional disease burden in Maryland:

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of Salmonella infection in Maryland (Table 1). The magnitude of the increase in Salmonella infection rate in Maryland is projected to be relatively small.***

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of hospitalizations for heart attack in Maryland (Table 1). The magnitude of the increase in heart attack hospitalization rate in Maryland is projected to be moderate.***

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of hospitalization for asthma in Maryland (Table 1). The magnitude of the increase in asthma hospitalization rate in Maryland is projected to be large.***

Table 1. Projected change in disease rates associated with extreme heat events in Maryland during summer months.

HEALTH OUTCOME	RATES IN SUMMER*			PROJECTION RANKING
	2010	2040	% Change	
SALMONELLA INFECTION	6.1	7.8	28.0	SMALL
HOSPITALIZATION FOR HEART ATTACK	38.2	64.3	68.4	MODERATE
HOSPITALIZATION FOR ASTHMA	29.4	69.6	136.8	LARGE

**Rate per 100,000 residents, calculated as a seasonal average.*

- *There will be considerable variability in the disease burden across the 24 counties in Maryland. The county level increases in disease burden may differ from the overall State level outlook.*

- *The increases in disease burden will not be uniform across all population subgroups. People with pre-existing medical conditions, children, low socioeconomic status, as well as those residing near coastal areas will be disproportionately impacted because they have pre-existing conditions that put them at higher risk, or because they lack adequate resources to help them adapt to the changing conditions.*

- *Specific projections related to vector-borne diseases including Lyme disease and West Nile Virus are not currently available.*

This section describes the baseline health assessments, risk estimates (exposure-response functions), and projection of future disease burden for the four diseases (step 2 of the BRACE framework) for each of the four pilot counties. The purpose of this disease burden projection mirrors that presented for the entire state, with the intention of highlighting the changing vulnerability and projections of disease burden based upon geography and factors that are inherent to those locations. This is an ongoing process that will need to be continually updated to reflect the improvements in scientific understanding related to the disease dynamics, mathematical modeling, as well as availability of more health data covering longer time frames and finer geographical resolution. The year 2040 was chosen because that was the last year for which the county and state level population projection was available from the Maryland Department of Planning. For this report, the disease projection was done for extreme heat events only during the summer months, rather than the entire year using the CWRF projections. Our rationale is that the intensity of extreme heat events are likely to be most pronounced during summer months. Furthermore, relationships between extreme heat events and health may operate by different mechanisms during the cold season. Future studies are needed to answer these questions. This projection relies on the high-end scenario (RCP 8.5). Since the risk of *Campylobacter* infection was not related to extreme heat events, the projections did not include Campylobacteriosis.

Baltimore City

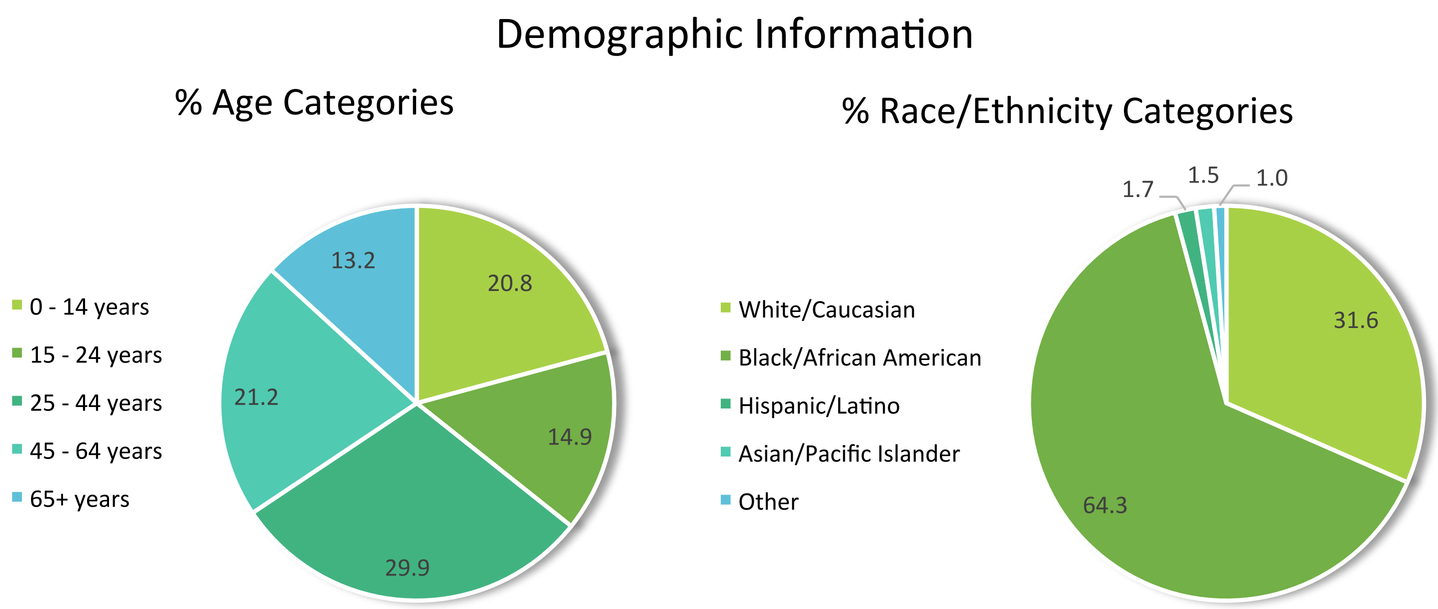
This section provides a county level overview of baseline health, vulnerability assessment, and disease burden projection for Baltimore City. Because of the limited number of cases, county level historical risk estimates for *Salmonella* and *Campylobacter* infections are not available.

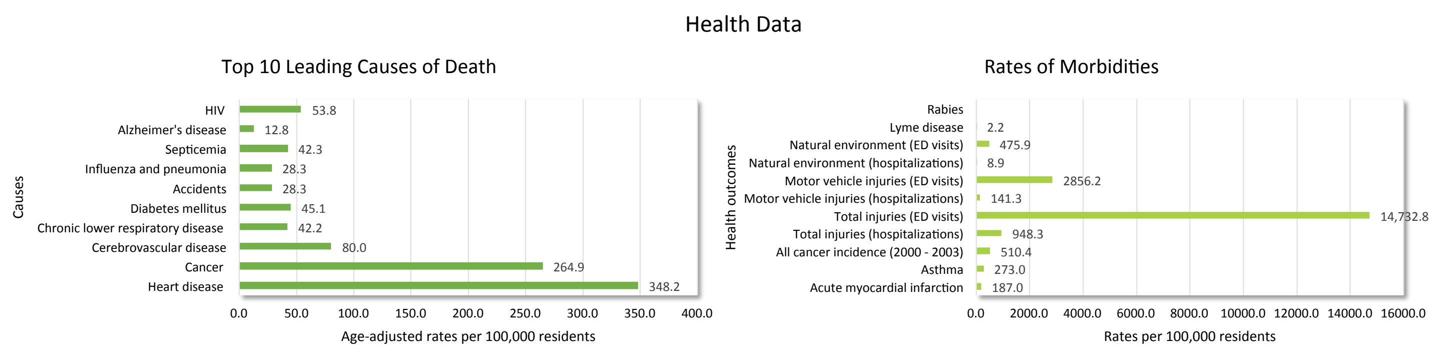
Baseline Health Assessment

- ***From 2000 (Figure 6) to 2010 (Figure 7) the demographics of Baltimore City have changed slightly. Baltimore City has a predominantly African American population (64%), followed by Caucasian (30%).***

- ***The leading causes of death are heart disease, cancer, stroke, cerebrovascular disease, diabetes, and HIV infection. Motor vehicle injuries continue to be the leading cause of morbidity.***

Figure 6. Demographic information for Baltimore City's population, in 2000.





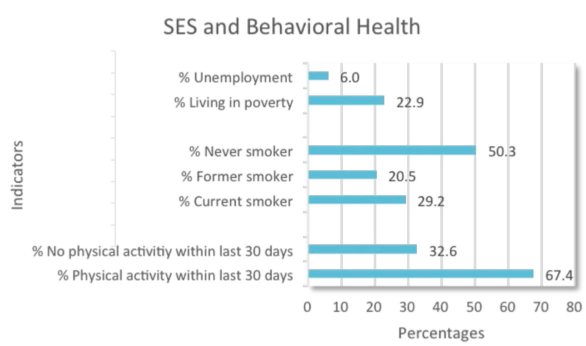
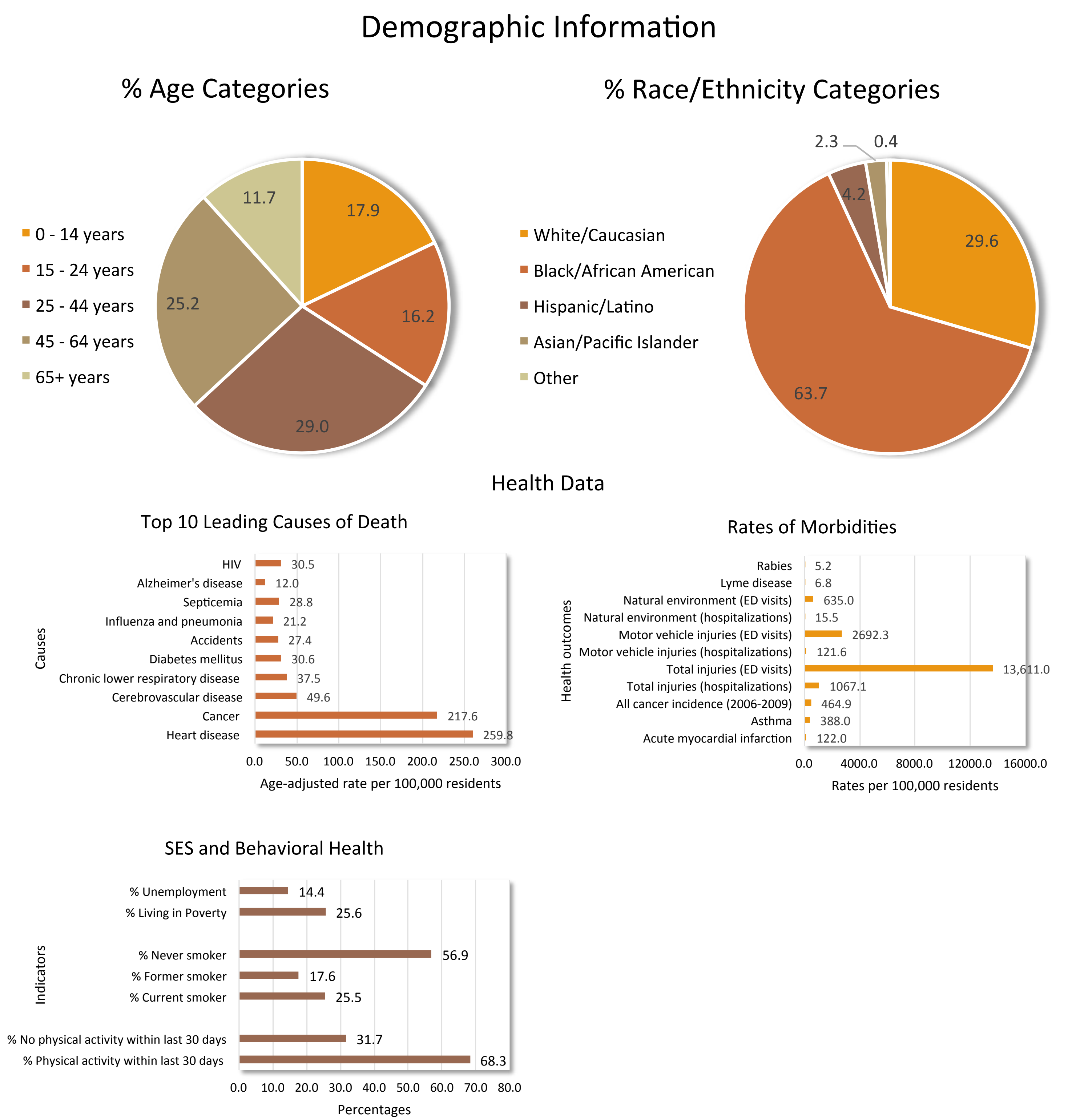


Figure 7. Demographic information for Baltimore City's population, in 2010.



Chronic disease

County level analysis for Baltimore City based on 2000-2012 data shows that:

- ***Exposures to extreme heat event during summer months increased the risk of hospitalization for heart attack by 43% among residents of Baltimore City (Table 2). This risk of hospitalization was considerably higher compared to Maryland as a whole (11%).***

- ***Exposures to extreme heat event during summer time increased the risk of hospitalization for asthma by 37% in Baltimore City (Table 3).***

- ***Exposure to extreme precipitation event during summer month increased the risk of hospitalization for asthma in Baltimore City by 16%. This value is similar to the one observed for Maryland as a whole (11%).***

Table 2. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat event and risk of hospitalization for heart attack in Baltimore City vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	ODDS RATIO (95% CI)
BALTIMORE CITY	OVERALL	1.09 (0.98 – 1.20)
MARYLAND	OVERALL	1.03 (1.00 – 1.06)
BALTIMORE CITY	SUMMER	1.43 (1.16 – 1.75)
MARYLAND	SUMMER	1.11 (1.05 – 1.17)

Table 3. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and risk of hospitalization for asthma in Baltimore City vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	HEAT	PRECIPITATION
		ODDS RATIO (95% CI)	
BALTIMORE CITY	OVERALL	1.10 (1.02 – 1.19)	1.00 (0.96 – 1.04)
MARYLAND	OVERALL	1.03 (1.00 – 1.07)	1.00 (0.98 – 1.02)
BALTIMORE CITY	SUMMER	1.36 (1.14 – 1.64)	1.16 (1.06 – 1.27)
MARYLAND	SUMMER	1.22 (1.15 – 1.33)	1.11 (1.06 – 1.17)

Climate Forecast

- ***Baltimore City is projected to have more extreme heat events in 2040 compared to 2010 (Table 4).***

Disease Burden Projection

- ***Compared to 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of Salmonella infection in Baltimore City. The magnitude of the increase in Salmonella infection rate is projected to be relatively small in Baltimore City (Table 5).***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the rate of hospitalization for heart attack in Baltimore City (Table 5). The magnitude of the increase in heart attack hospitalization rate is projected to be large in Baltimore City.***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the hospitalization rates for asthma (Table 5). The magnitude of the increase in asthma hospitalization rate is projected to be large in Baltimore City.***

Table 4. Projected number of extreme heat and precipitation events (yearly) for Baltimore City by Climate Forecast Model.

EXTREME EVENTS	YEAR	BALTIMORE CITY			MARYLAND		
		CWRF	A2*	B1*	CWRF	A2*	B1*
HEAT	2010	34	N/A	N/A	33	N/A	N/A
	2040	46	25	22	58	25	22
PRECIPITATION	2010	40	N/A	N/A	38	N/A	N/A
	2040	43	N/A	N/A	41	N/A	N/A

***A2 is the Regional Growth scenario, while B1 is the Service Economy scenario.*

Table 5. Projected change in disease rates related to extreme heat events in Baltimore City during summer months.

HEALTH OUTCOME	RATES IN SUMMER *			PROJECTION RANKING
	2010	2040	% CHANGE	
SALMONELLA INFECTION	9.7	11.0	13.5	SMALL
HOSPITALIZATION FOR HEART ATTACK	52.8	121.0	129.0	LARGE
HOSPITALIZATION FOR ASTHMA	86.6	180.2	108.0	LARGE

***Rate per 100,000 residents, calculated as a seasonal average.*

Prince George's County

This section provides a county level overview of baseline health, vulnerability assessment, and disease burden projection for Prince George's County. Because of the limited number of cases, county level historical risk estimates for *Salmonella* and *Campylobacter* infections are not available.

Baseline Health Assessment

- ***From 2000 (Figure 8) to 2010 (Figure 9) the demographics of Prince George's County changed slightly, with an 8% growth in Hispanic population and 5% reduction in Caucasian population.***

- ***The leading causes of death continue to be heart disease and cancer. Motor vehicle injuries continue to be a leading cause of morbidity.***

- ***The unemployment rate in Prince George's County increased from 4.1% in 2000 to 10.8% in 2010.***

- ***The percentage of the population that currently smokes declined from 16.5% in 2000 to 13.6% in 2010.***

Chronic Disease

Results based on county level analysis using 2000-2012 data showed that:

- ***Evidence regarding exposure to extreme heat events during summer months and increased risk of hospitalization for heart attack in Prince George's County is not conclusive (Table 6).***

- ***Exposure to summertime extreme heat events increased the risk of hospitalization for asthma by 20% in Prince George's County (Table 7).***

- ***Evidence regarding exposure to summertime extreme precipitation events and increased risk of hospitalization for asthma in Prince George's County (Table 7) is not conclusive.***

Climate Forecast

- ***Prince George's County is projected to experience more extreme heat events during 2040 compared to 2010 (Table 8).***

- ***The projected increase in number of extreme heat events in Prince George's County is relatively lower compared to Maryland.***

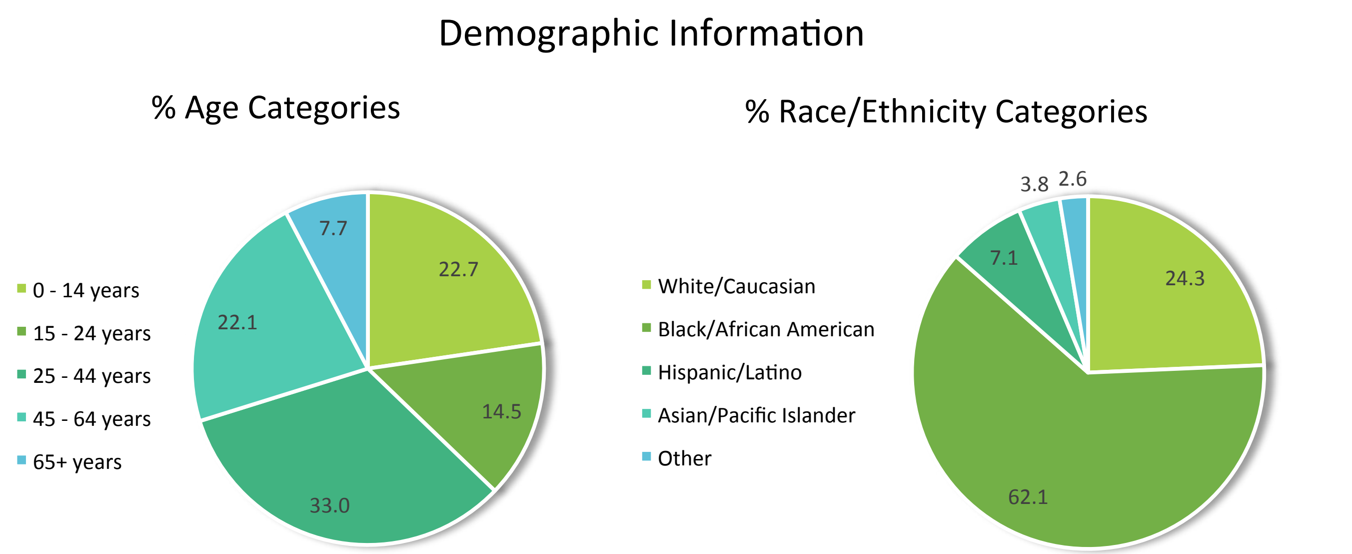
Disease Burden Projection

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase Salmonella infection rates in Prince George's County (Table 9). The magnitude of increase in Salmonella infection rate is projected to be relatively small in Prince George's County.***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the hospitalization rates for heart attack in Prince George's County (Table 9). The magnitude of the increase in heart attack hospitalization rate is projected to be relatively small in Prince George's County.***

▶ ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase the hospitalization rates for asthma in Prince George's County. The magnitude of the increase in hospitalization rates for asthma is projected to be moderate in Prince George's County.***

Figure 8. Demographic information for Prince George's County population, in 2000.



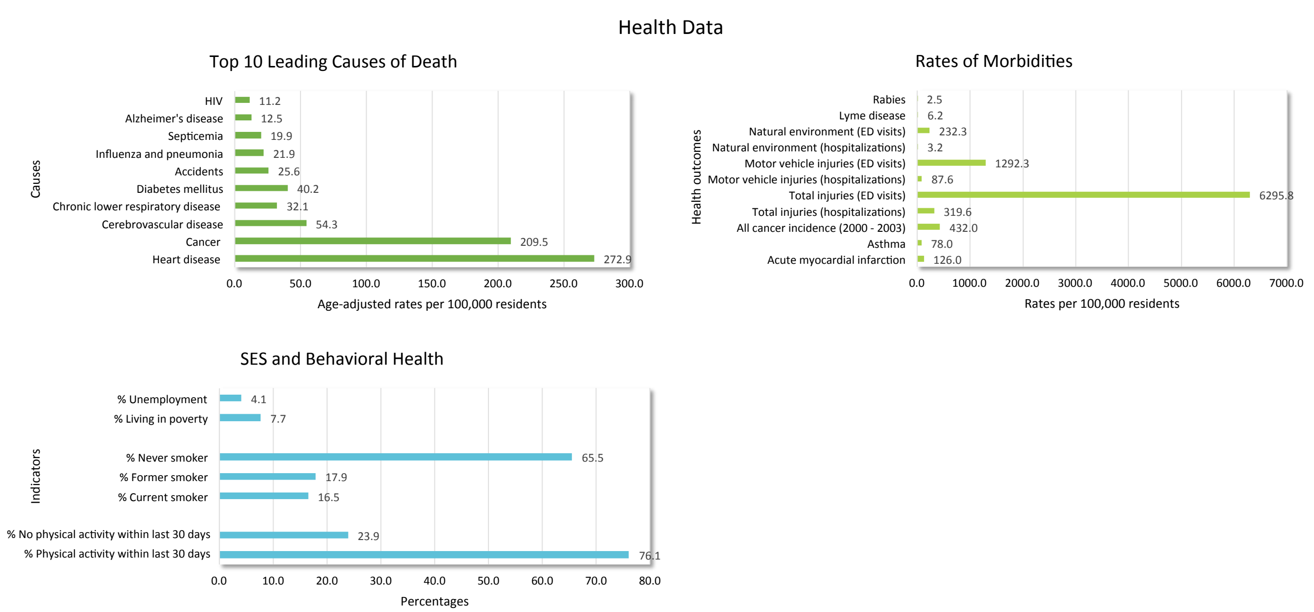


Figure 9. Demographic information for Prince George's County population, in 2010.

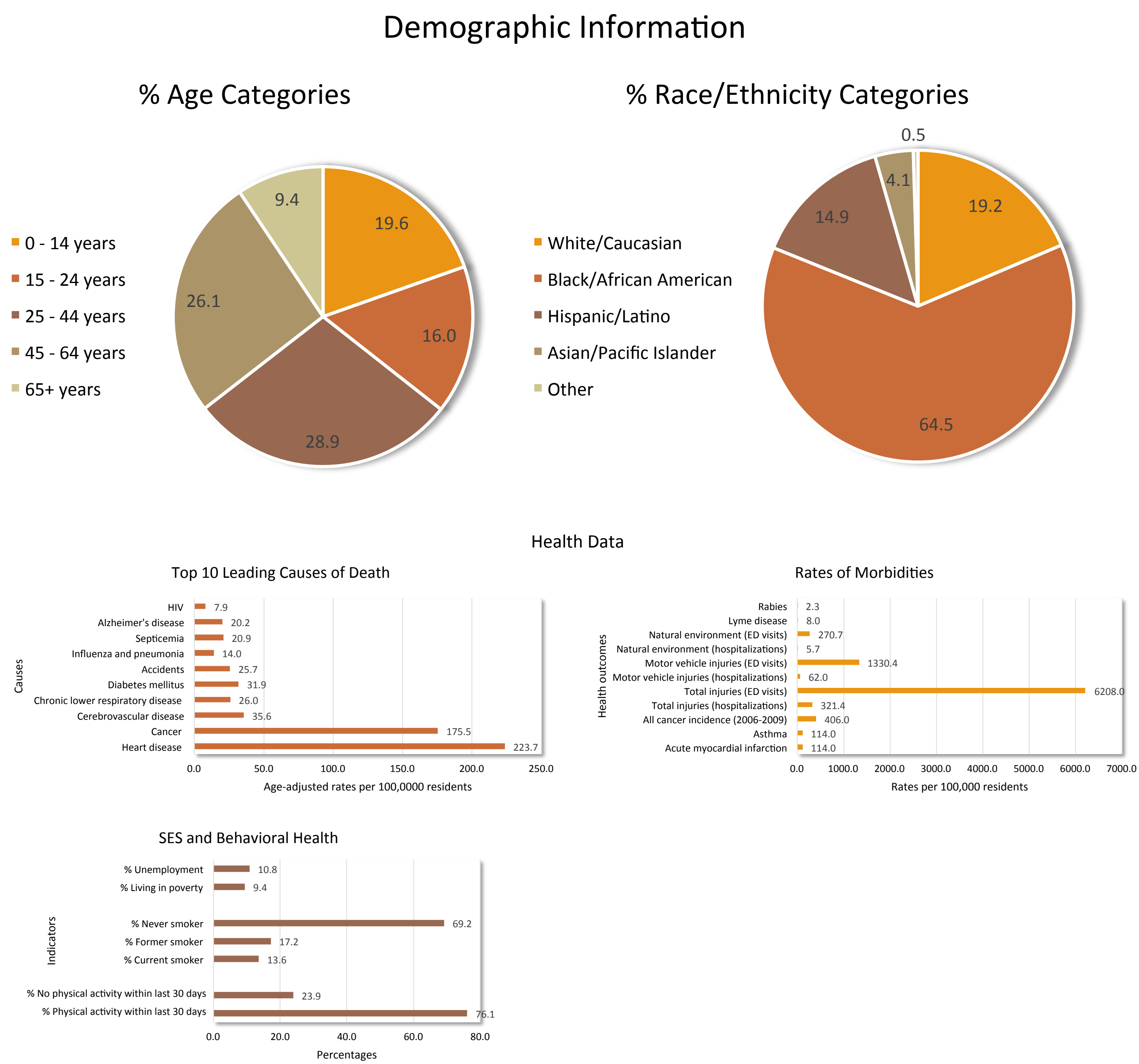


Table 6. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat event and risk of hospitalization for heart attack in Prince George's County, Years 2000-2012.

LOCATION	TIME OF YEAR	ODDS RATIO (95% CI)
PRINCE GEORGE'S COUNTY	OVERALL	0.99 (0.91 – 1.08)
MARYLAND	OVERALL	1.03 (1.00 – 1.06)
PRINCE GEORGE'S COUNTY	SUMMER	1.06 (0.91 – 1.24)
MARYLAND	SUMMER	1.11 (1.05 – 1.17)

Table 7. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and risk of hospitalization for asthma in Prince George's County vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	HEAT	PRECIPITATION
		ODDS RATIO (95% CI)	
PRINCE GEORGE'S COUNTY	OVERALL	1.02 (0.93 – 1.11)	1.05 (0.99 – 1.13)
MARYLAND	OVERALL	1.03 (1.00 – 1.07)	1.00 (0.98 – 1.02)
PRINCE GEORGE'S COUNTY	SUMMER	1.20 (1.01 – 1.41)	1.10 (0.95 – 1.27)
MARYLAND	SUMMER	1.22 (1.15 – 1.33)	1.11 (1.06 – 1.17)

Table 8. Projected number of extreme events (yearly) for Prince George's County by Climate Forecast Model.

Extreme Events	Year	Prince George's County			Maryland		
		CWRF	A2*	B1*	CWRF	A2*	B1*
HEAT	2010	33	N/A	N/A	33	N/A	N/A
	2040	48	25	21	58	25	22
PRECIPITATION	2010	39	N/A	N/A	38	N/A	N/A
	2040	44	N/A	N/A	41	N/A	N/A

**A2 is the Regional Growth scenario, while B1 is the Service Economy scenario.*

Table 9. Projected change in disease rate in Prince George's County during summer months.

HEALTH OUTCOME	RATES IN SUMMER *			PROJECTION RANKING
	2010	2040	% Change	
SALMONELLA INFECTION	4.1	4.8	16.9	SMALL
HOSPITALIZATION FOR HEART ATTACK	24.2	29.7	22.5	SMALL
HOSPITALIZATION FOR ASTHMA	22.2	38.9	75.0	MODERATE

**=Rate per 100,000 residents, calculated as a seasonal average.*

Washington County

This section provides a county level overview of baseline health, vulnerability assessment, and disease burden projection for Washington County. Because of the limited number of cases, county level historical risk estimates for *Salmonella* and *Campylobacter* infections are not available.

Baseline Health Assessment

- ***From 2000 (Figure 10) to 2010 (Figure 11) the demographics of Washington County has changed very little. Washington County has a predominantly Caucasian population (85%) followed by non-Hispanic blacks (10%).***

- ***The leading causes of death in Washington County are heart disease and cancer. Motor vehicle injures continue to be a leading cause of morbidity.***

- ***The percentage of the population unemployed and living in poverty increased in Washington County between 2000 and 2010.***

- ***The percentage of the population who currently smoke decreased from 24% in 2000 to 18% in 2010.***

Chronic Disease

County level analysis for Washington County based on 2000-2012 data showed that:

- ***Exposure to summertime extreme heat events was not related to the risk of hospitalization for heart attack in Washington County (Table 10). This risk was different compared to the increased risk (11%) observed in the rest of Maryland.***

- ***Exposure to summertime extreme heat events increased the risk of hospitalization for asthma among residents of Washington County by 76%. This increase in risk was considerably higher than that observed for Maryland as a whole (22%) (Table 11).***

- ***Exposure to extreme precipitation events was not related to hospitalization for asthma in Washington County (Table 11).***

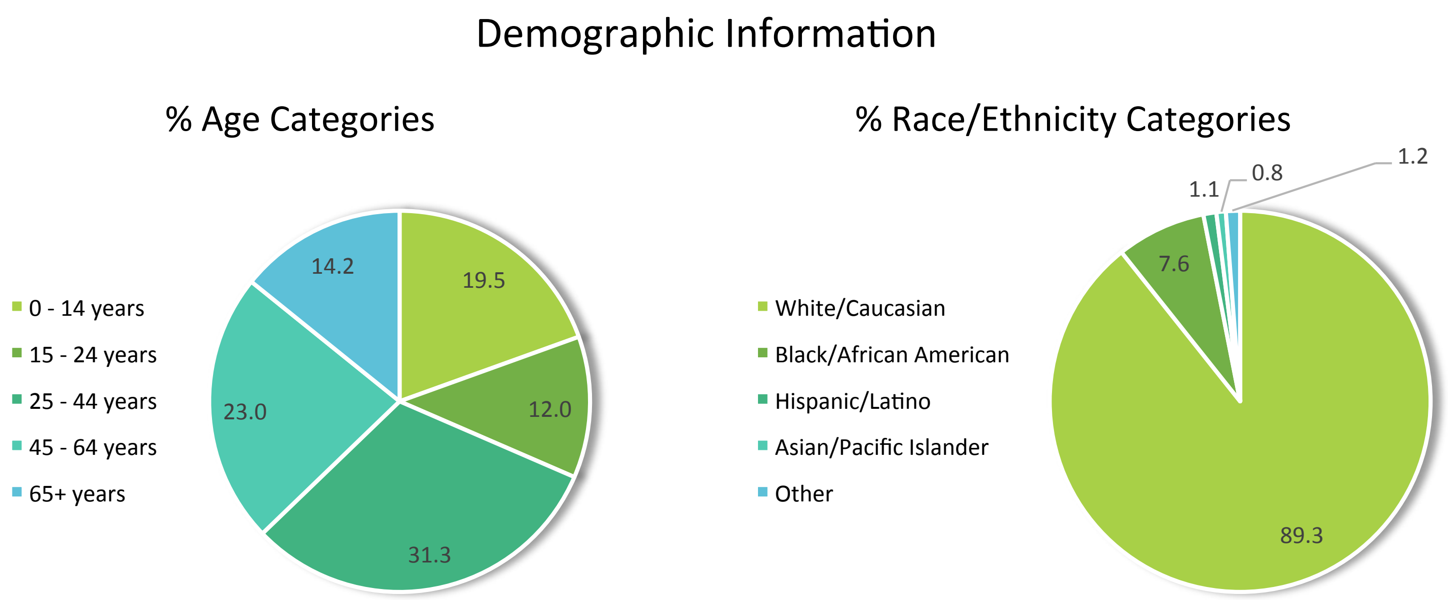
Climate Forecast

- ***Washington County is projected to experience more extreme heat events in 2040 compared to 2010 (Table 12).***

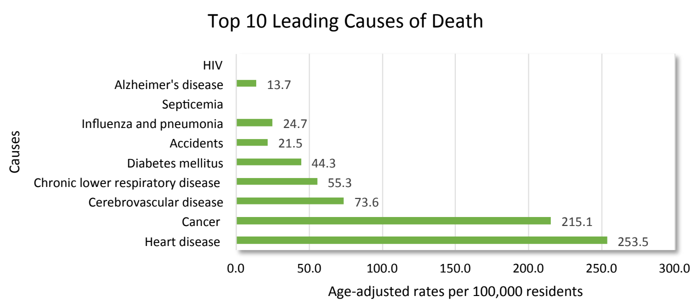
Table 10. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat event and risk of hospitalization for heart attack in Washington County vs. Maryland, Years 2000-2012.

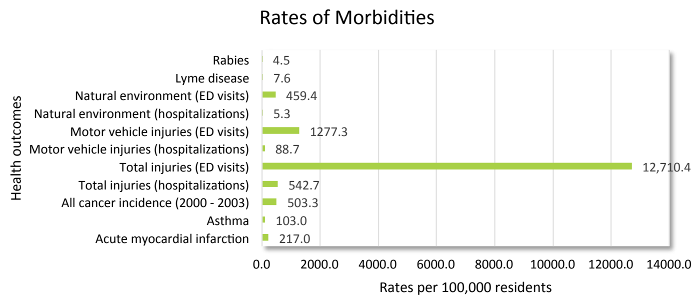
LOCATION	TIME OF YEAR	ODDS RATIO (95% CI)
WASHINGTON COUNTY	OVERALL	0.98 (0.83 – 1.15)
MARYLAND	OVERALL	1.03 (1.00 – 1.06)
WASHINGTON COUNTY	SUMMER	0.96 (0.71 – 1.30)
MARYLAND	SUMMER	1.11 (1.05 – 1.17)

Figure 10. Demographic information for Washington County's population, in 2000.



Health Data





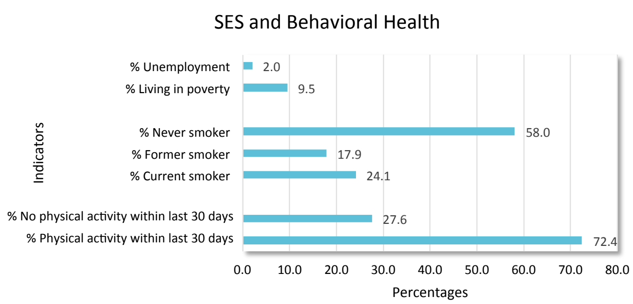
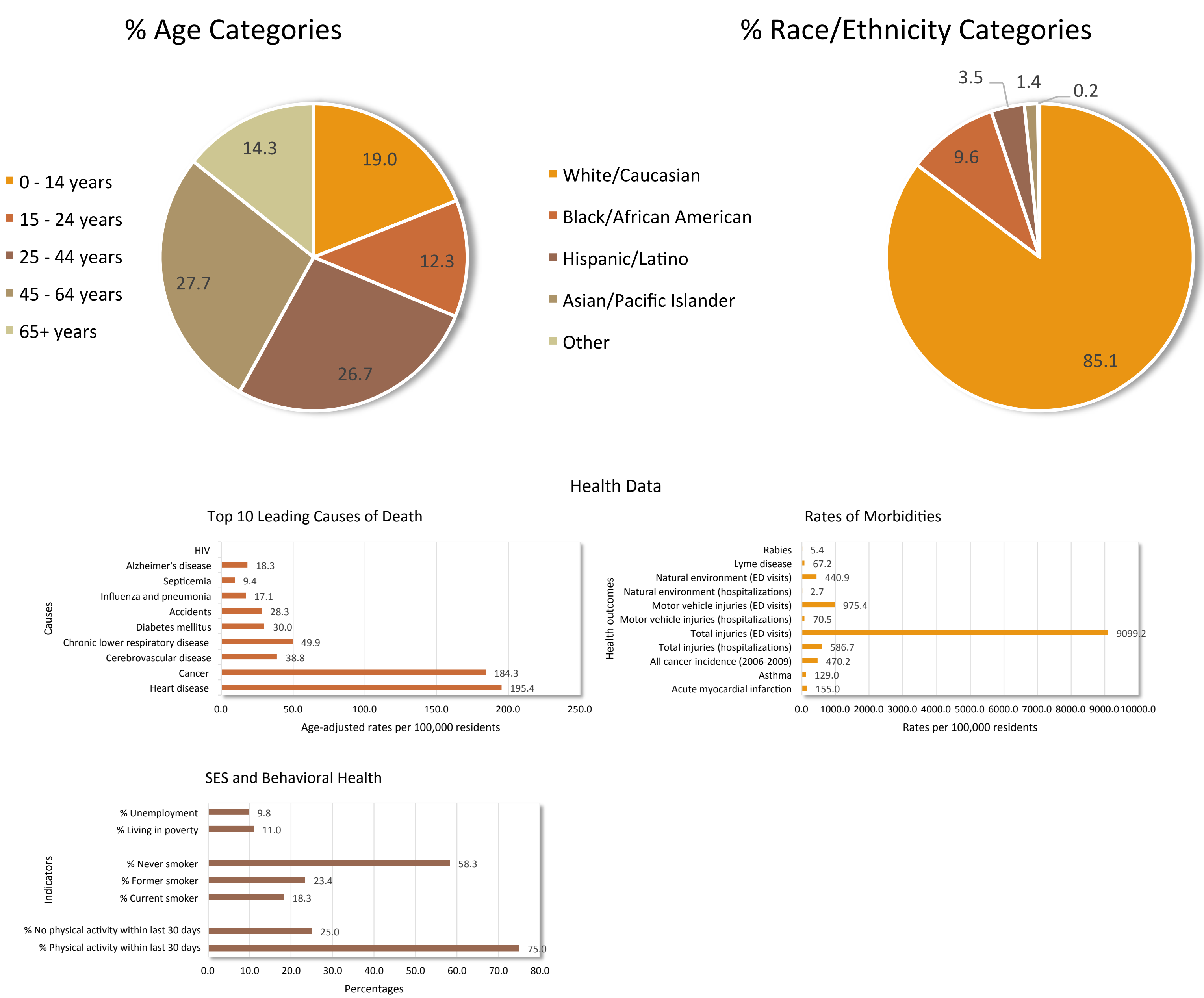


Figure 11. Demographic information for Washington County's population, in 2010.



Disease Burden Projection

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase Salmonella infection rates in Washington County (Table 13). The magnitude of the increase in Salmonella infection rate is projected to be relatively small in Washington County.***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to not contribute to an increase in hospitalization rates for heart attack in Washington County (Table 13).***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase hospitalization rates for asthma in Washington County (Table 13). The magnitude of the increase in asthma hospitalization rate is projected to be large.***

Table 11. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and risk of hospitalization for asthma in Washington County vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	HEAT	PRECIPITATION
		ODDS RATIO (95% CI)	
WASHINGTON COUNTY	OVERALL	1.23 (0.97 – 1.55)	1.04 (0.88 – 1.23)
MARYLAND	OVERALL	1.03 (1.00 – 1.07)	1.00 (0.98 – 1.02)
WASHINGTON COUNTY	SUMMER	1.76 (1.09 – 2.84)	0.91 (0.63 – 1.31)
MARYLAND	SUMMER	1.22 (1.15 – 1.33)	1.11 (1.06 – 1.17)

Table 12. Projected number of extreme events (yearly) for Washington County by Climate Forecast Model

EXTREME EVENTS	YEAR	WASHINGTON COUNTY			MARYLAND		
		CWRF	A2*	B1*	CWRF	A2*	B1*
HEAT	2010	26	N/A	N/A	33	N/A	N/A
	2040	45	24	20	58	25	22
PRECIPITATION	2010	37	N/A	N/A	38	N/A	N/A
	2040	45	N/A	N/A	41	N/A	N/A

**A2 is the Regional Growth scenario, while B1 is the Service Economy scenario.*

Table 13. Projected change in disease rate for Washington County during summer months.

HEALTH OUTCOME	RATES IN SUMMER *			PROJECTION RANKING
	2010	2040	% Change	
SALMONELLA INFECTION	4.9	5.9	21.4	SMALL
HOSPITALIZATION FOR HEART ATTACK	49.2	39.9	-19.0	UNDETERMINED
HOSPITALIZATION FOR ASTHMA	19.8	91.3	361.0	LARGE

**=Rate per 100,000 residents, calculated as a seasonal average.*

Wicomico County

This section provides a county level overview of baseline health, vulnerability assessment, and disease burden projection for Wicomico County. Because of the limited number of cases, county level historical risk estimates for *Salmonella* and *Campylobacter* infections are not available.

Baseline Health Assessment

- ***From 2000 (Figure 12) to 2010 (Figure 13) the demographic characteristics of Wicomico County changed marginally. The county population is predominantly Caucasian (69%) followed by non-Hispanic black (24%).***

- ***The leading causes of death are heart disease and cancer. Motor vehicle injures continue to be a leading cause of morbidity.***

- ***Unemployment and poverty went up in Wicomico County in 2010 (9.3% and 18.3%, respectively) compared to 2000 (3.7% and 12.8%, respectively).***

- ***The percentage of the population that are current smokers increased slightly from 21.5% in 2000 to 22.7% in 2010. This is opposite to the statewide decreasing trend.***

Chronic Disease

County level analysis for Wicomico County using 2000-2012 data shows that:

- ***Exposure to extreme heat events during summer months was not related to risk of hospitalization for heart attack in Wicomico County (Table 14).***

- ***Evidence regarding exposure to extreme heat events during summer months and increased risk of hospitalization for asthma in Wicomico County was inconclusive (Table 15).***

- ***Exposure to extreme precipitation events during summer months was not related to hospitalization for asthma in Wicomico County (Table 15).***

Climate Forecast

- ***Wicomico County is projected to experience an increase in number of extreme heat events in 2040 compared to 2010 (Table 16), while extreme precipitation are projected to remain relatively unchanged.***

Disease Burden Projection

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase Salmonella infection rates in Wicomico County (Table 17). The magnitude of the increase in Salmonella infection rate is projected to be relatively small.***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to not contribute to an increase in hospitalization rates for heart attack in Wicomico County (Table 17).***

- ***Compared with 2010, increases in the frequency of extreme heat events during summer months in 2040 are projected to increase hospitalization rates for asthma in Wicomico County (Table 17). The magnitude of the increase in asthma hospitalization rate is projected to be relatively small in Wicomico County.***

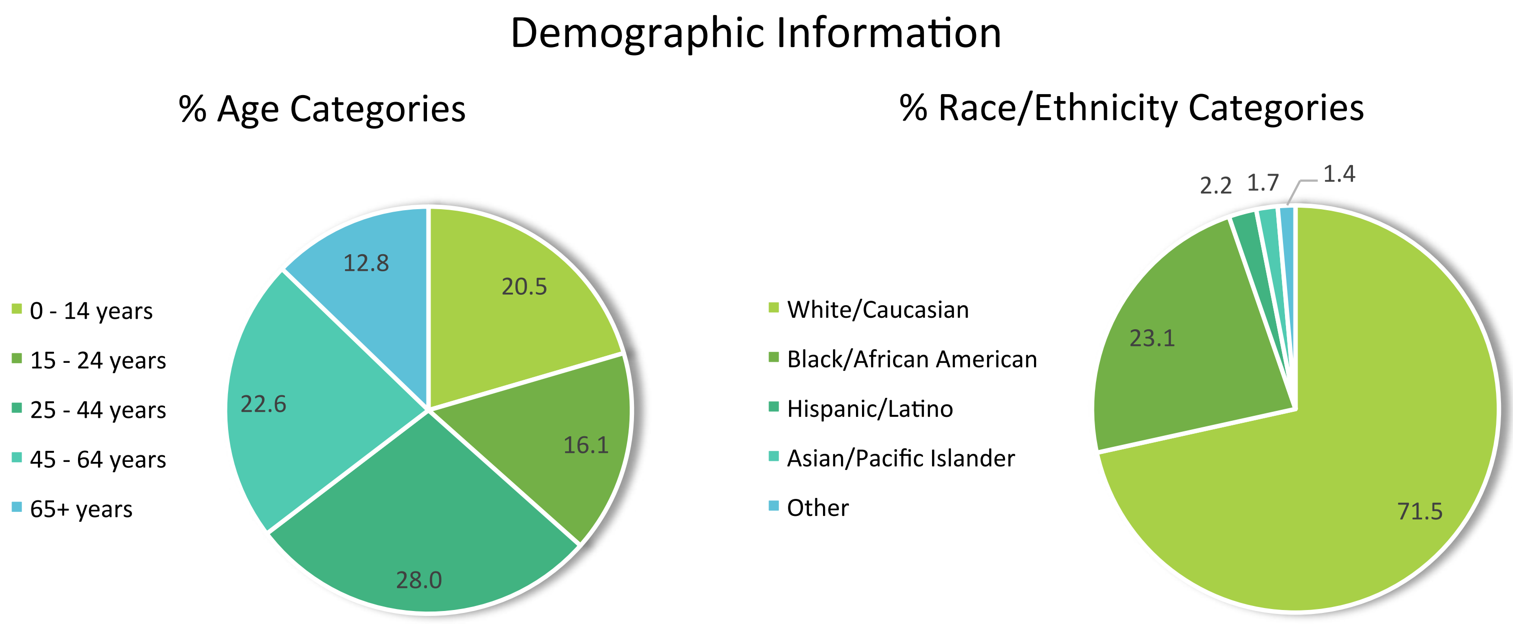
Table 14. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat event and risk of hospitalization for heart attack in Wicomico County vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	ODDS RATIO (95% CI)
WICOMICO COUNTY	OVERALL	1.08 (0.92 – 1.23)
MARYLAND	OVERALL	1.03 (1.00 – 1.06)
WICOMICO COUNTY	SUMMER	1.00 (0.74 – 1.35)
MARYLAND	SUMMER	1.11 (1.05 – 1.17)

Table 15. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and risk of hospitalization for asthma in Wicomico County vs. Maryland, Years 2000-2012.

LOCATION	TIME OF YEAR	HEAT	PRECIPITATION
		ODDS RATIO (95% CI)	
WICOMICO COUNTY	OVERALL	0.92 (0.73 – 1.15)	0.99 (0.83 – 1.19)
MARYLAND	OVERALL	1.03 (1.00 – 1.07)	1.00 (0.98 – 1.02)
WICOMICO COUNTY	SUMMER	1.22 (0.77 – 1.94)	0.90 (0.57 – 1.43)
MARYLAND	SUMMER	1.22 (1.15 – 1.33)	1.11 (1.06 – 1.17)

Figure 12. Demographic information for Wicomico County's population, in 2000.



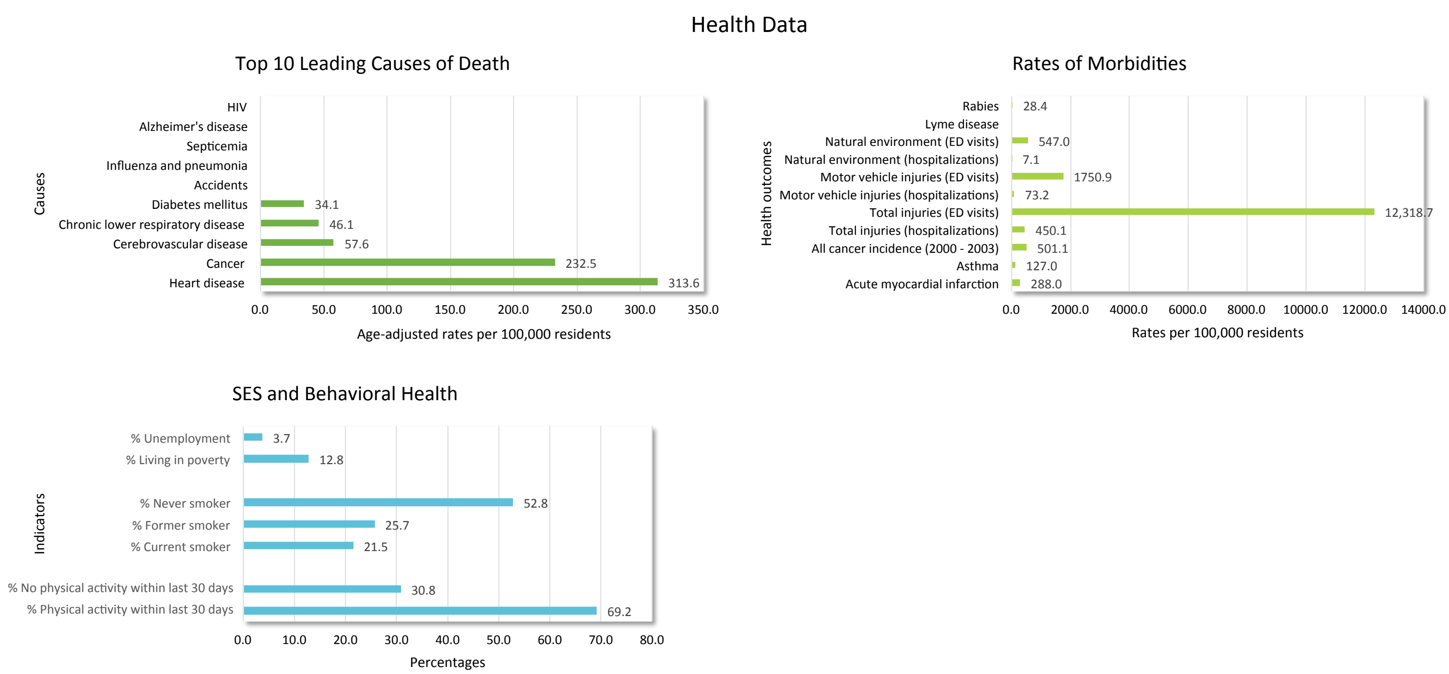


Figure 13. Demographic information for Wicomico County's population, in 2010.

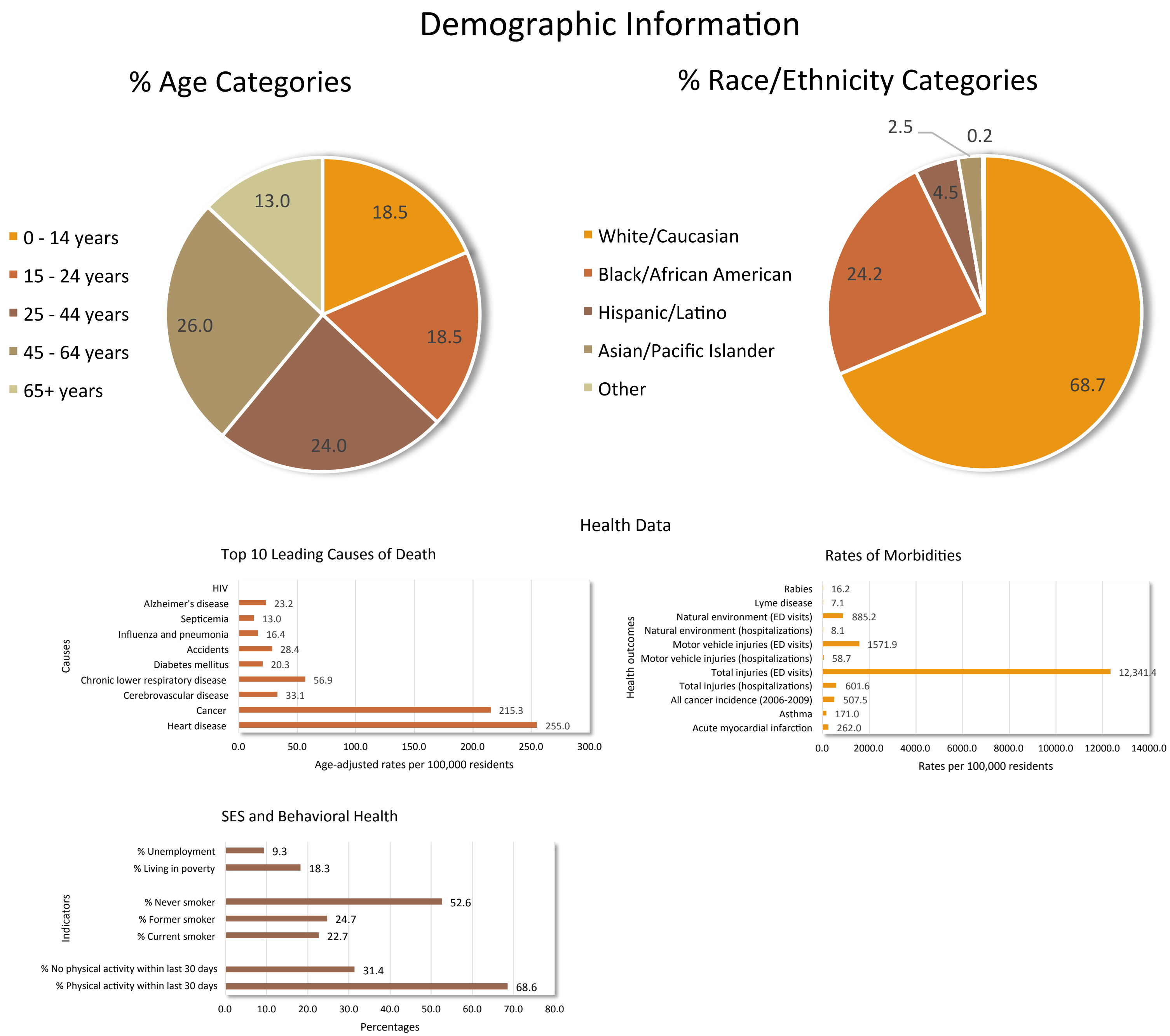


Table 16. Projected number of extreme events (yearly) for Wicomico County by Climate Forecast Model.

Extreme Events	Year	Wicomico County			Maryland		
		CWRF	A2*	B1*	CWRF	A2*	B1*
HEAT	2010	31	N/A	N/A	33	N/A	N/A
	2040	38	28	24	58	25	22
PRECIPITATION	2010	36	N/A	N/A	38	N/A	N/A
	2040	37	N/A	N/A	41	N/A	N/A

**A2 is the Regional Growth scenario, while B1 is the Service Economy scenario.*

Table 17. Projected change in disease rate for Wicomico County during summer months.

HEALTH OUTCOME	RATES IN SUMMER *			PROJECTION RANKING
	2010	2040	% Change	
SALMONELLA INFECTION	16.6	17.9	7.9	SMALL
HOSPITALIZATION FOR HEART ATTACK	50.0	50.0	0	NO CHANGE
HOSPITALIZATION FOR ASTHMA	22.9	31.7	38.5	SMALL

**=Rate per 100,000 residents, calculated as a seasonal average.*

CHAPTER 5: UNCERTAINTY

There are several sources of uncertainties associated with the health outcomes, exposure metrics, exposure-response functions, climate projections, and disease burden projections that merit further discussion. For instance, outcomes such as *Salmonella* infections and *Campylobacter* infections described in this report are known to be considerably underreported. This may lead to underestimation of the exposure-response function. In addition, information on specific outbreaks that might have contributed to the temporal clustering of outcomes was missing. Also, when calculating county level projections for *Salmonella* infections, only the statewide incident rate ratio (exposure-response risk estimate) from 2002-2012 was available, as some of the counties had few cases to generate reliable risk estimates. For the analysis related to hospitalization for asthma and heart attack, information related to hospital readmission was missing. For asthma hospitalization, information on medication use was not available. Similarly, missing historical weather data also might have contributed to the uncertainty in exposure assessments related to extreme events. Furthermore, the analysis described in this report only accounted for the frequency of extreme events, not their intensity or duration (i.e., all extreme events were treated equally). In addition, the spatial unit of analysis was county, meaning the analyses did not account for potential "between person variability" for exposure to extreme events for individuals living in a county.

Limitations related to the climate projections have been described previously.[42,65,66] There are uncertainties associated with different approaches in modeling natural climate variability, as well as unknowns regarding emission scenarios and population dynamics in future decades. These uncertainties can have considerable impact on climate projections. The detailed discussions related to these uncertainties as well as specific approaches to dealing with these uncertainties are beyond the scope of this report. Interested readers in this topic are encouraged to refer to previous works.[65,66]

Disease projections were based on four factors: 1) empirically derived Maryland specific exposure-response functions; 2) baseline prevalence of health outcomes in 2000-2010; 3) population projections obtained from the Maryland Department of Planning; and 4) future projections of extreme events obtained from CWRF RCP 8.5. Thus, the burden projection described here represents the high-end scenarios. The uncertainties associated with each of these components were incorporated into our disease projections, so interpretation should be focused on the trend rather than the absolute numbers. Subsequent work will focus on additional health outcomes, as well as on uncertainty analysis and incorporation of multiple models with range of scenarios and joint approaches to disease projections. Future work will also focus on how changes in demographic composition as well as adaptation strategies may affect the projected burden of disease.

CHAPTER 6: CONCLUSIONS

The first key recommendation under human health in the Phase II report of the Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change was to: ***Conduct vulnerability assessments to gain a better understanding of risks and inform preventative responses***. This Climate and Health Profile report represents the first systematic effort to do just that, using the best available data to identify the public health impacts of climate change in Maryland for a number of health outcomes. The report provides the first quantitative estimate of how extreme events are affecting the health of Marylanders now and how the changing climate could affect health in future decades (up to 2040). However, the value of this report, particularly the disease projections, lies less in any specific estimate than in the discussion it is intended to engender amongst public health professionals, the public, and policy makers as Maryland continues to implement a Public Health Strategy for Climate Change. These projections need to be updated periodically to reflect the improvements in scientific understandings related to the disease dynamics, mathematical modeling, as well as availability of more health data covering a longer time frame and finer geographical resolution.

The next phase of the BRACE framework calls for the development and implementation of interventions based on anticipated vulnerabilities. DHMH will continue to work with the State's local jurisdictions to develop and implement adaptive interventions based on vulnerabilities identified in the Profile. In addition, the Profile report will be disseminated to the Climate Change Commission and other State agencies as the State continues to develop and refine its Climate Action Plan.

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APPENDIX 1. OVERVIEW OF METHODS USED AND RESULTS

MARYLAND DEPARTMENT OF HEALTH AND MENTAL HYGIENE

BASELINE HEALTH ASSESSMENT

Source of Data:

The presentations of baseline health data are adapted from two other documents: the Baltimore City neighborhood health profiles and the Environmental Public Health Tracking (EPHT) county health profiles, which provide cross-sectional data for various neighborhoods in Baltimore City, and the 24 counties in Maryland, respectively. An abbreviated version was developed to focus on a smaller collection of variables for the four pilot counties and the State of Maryland.

Data from the years 2000, 2005, and 2010 were obtained from the U.S. Census Bureau, American Community Survey (ACS), Maryland Environmental Public Health Tracking, Maryland Behavioral Risk Factor Surveillance System (BRFSS), Maryland Vital Statistics Administration (VSA) Annual Reports, Governor's Office of Crime Control & Prevention, Center for Zoonotic and Vector-Borne Diseases, and Health Services Cost Review Commission (HSCRC). Minor changes in variable names occurred between different years of the United States census and were noted in the documentation. Percentages or rates per 100,000 residents were calculated with counts and county population.

Demographic And Socioeconomic Indicators Include:

total population; population by gender; population by age/ethnicity categories: white/ Caucasian, black/African American, Hispanic/ Latino, Asian/Pacific Islander, other; population by age categories; median household income; percentage living in poverty; percentage unemployment; and rate of violent and property crimes.

Major health indicators include:

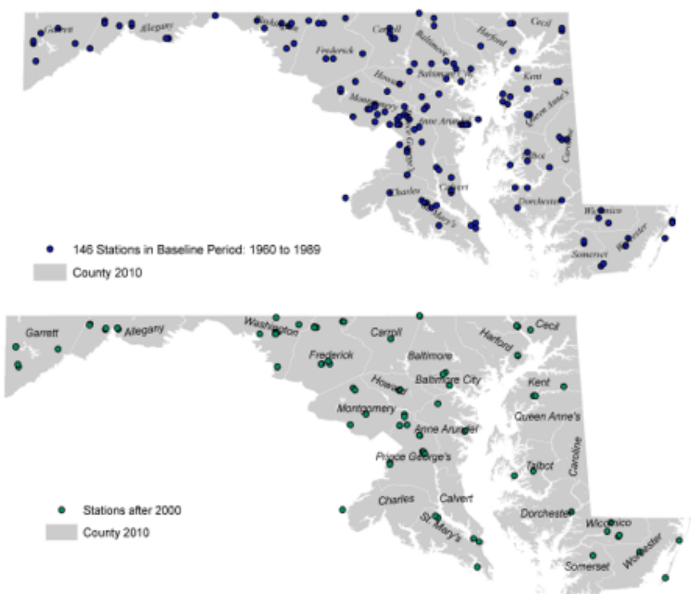
life expectancy at birth; rate of all-cause mortality; birth rate; infant mortality rate; percentage low birth weight; percentage elevated blood lead levels in children; rates of top 10 leading causes of death; rate of acute myocardial infarction (heart attack); rate of asthma hospital discharges; rate of cancer incidence; rate of hospitalizations and emergency department visits for total injuries, motor vehicle injuries, and natural environment-related injuries; rate of Lyme disease and rabies. Behavioral risk factors included physical activity and smoking status. For each individual year of data, statistics for the county are compared to those for the entire state of Maryland. In addition, changes in percentages or rates were calculated between 2005 and 2000, 2010 and 2000, and 2010 and 2005. If the difference is greater than 20%, a notation is indicated next to the county value as to whether the discrepancy is higher (+) or lower (-) than the state value. Data were input into excel spreadsheets in order to facilitate any subsequent data analyses with statistical software programs or spatial mapping programs.

EXTREME EVENTS IN MARYLAND DURING 1960-2012

We obtained daily weather data from the National Climatic Data Center website for the 1960-2012 period, including daily maximum temperature (TMAX) and precipitation (PRCP).[67] For counties with multiple stations (Figure 14) we calculated an average of the multiple stations. If a county did not have stations, we borrowed information from stations that were located within a 30 km radius of the county boundary or set it to "missing" if no stations were available within the

30 km radius. In the complete dataset, 99% of all counties had less than 1.5% missing data and there was no spatial pattern with regard to the location of missing data.

Figure 14. Location of weather stations in Maryland.



We used daily TMAX and PRCP for the 1960-1989 period to calculate county-specific baselines for a given calendar day using a 31-day window that centered on the particular calendar day. For example, the baseline data for Baltimore County for May 25th consisted of all daily observations for Baltimore County from May 10th to June 9th from 1960-1989. Based on the distribution of this data, we identified the 90th and 95th percentile values of PRCP and TMAX, referred to as Extreme Precipitation Threshold 90th percentile (EPT_{90}) and Extreme Heat Threshold 95th percentile (ETT_{95}). Calendar day specific PRCP and TMAX value for each county were compared to their respective EPT_{90} and ETT_{95} and assigned a value of "1" if they exceeded the thresholds, and "0" otherwise. We then summed these "extreme heat events" and "extreme precipitation events" over the calendar month for each county during the 1960-2012 period. We looked at how the monthly, seasonal, or yearly frequency of the extreme heat and precipitation events changed over time.

Figure 15. Temporal trend in extreme heat events (1960-2010), by season.

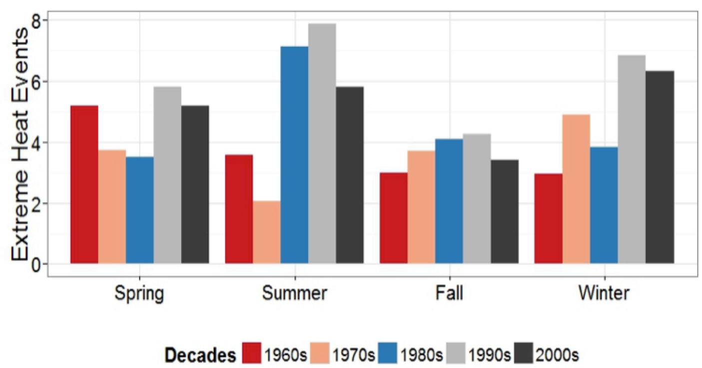


Figure 16. Temporal trend in extreme precipitation events (1960-2010), by season.

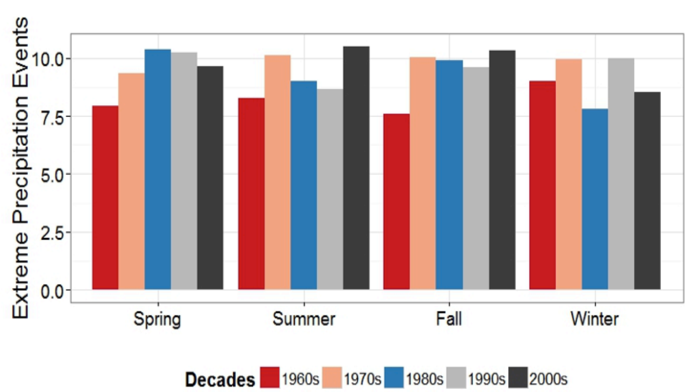
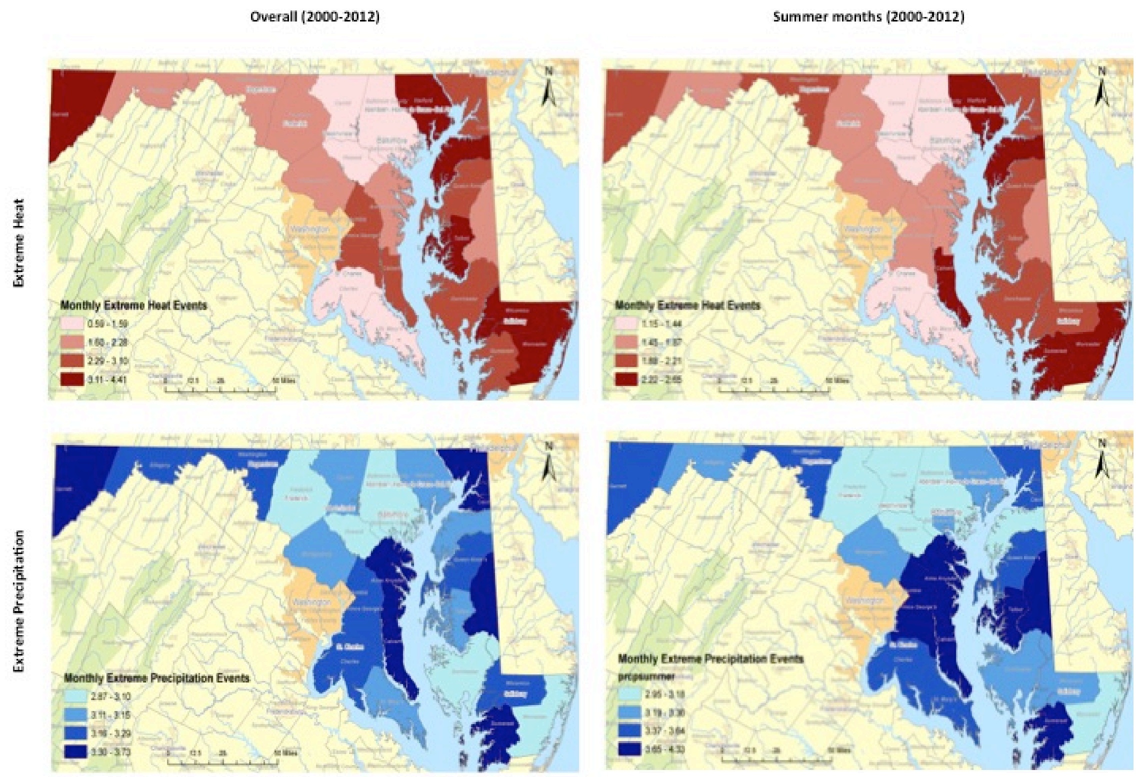


Figure 17 shows the average monthly number of extreme heat and precipitation events across different counties in Maryland during 2000-2012, for which we have the health data. These maps show differential patterns of extreme events across geographical areas.

Figure 17. Number of extreme events by county, for overall years and during summer months (2000-2012).



CLIMATE PROJECTIONS

Projections for the frequency of extreme heat events, shown in Figure 18, at the county level across Maryland were obtained from the U.S. Centers for Disease Control National Environmental Public Health Tracking Program. These projections are based on two scenarios, low emissions with a service economy (B1) and high emissions with regional growth (A2), as outlined by the United Nations International Panel on Climate Change (IPCC). The B1 scenario emphasizes integrated global economic, social, and environmental sustainability without additional climate initiatives, whereas the A2 scenario emphasizes fragmented, localized initiatives centered on self-reliance and ever-increasing population projections.[4] These scenarios, representing two divergent paths, were developed using climate modeling tools that incorporate future projections of climate forcing agents.
The CDC Tracking data used the 98th percentile thresholds to identify extreme heat event. In addition to the CDC Tracking data, additional climate projection data was

obtained from the Climate extension of the Weather Research and Forecasting model (CWRF).[3] It includes numerous improvements in representation of physical processes and integration of external (top, surface, lateral) forcings that are crucial to climate scales, including interactions between land–atmosphere–ocean, convection–microphysics and cloud–aerosol–radiation, and system consistency throughout all process modules.[68,69] It is built with a comprehensive ensemble of many alternate mainstream parameterization schemes for each of several key physical processes.[70]

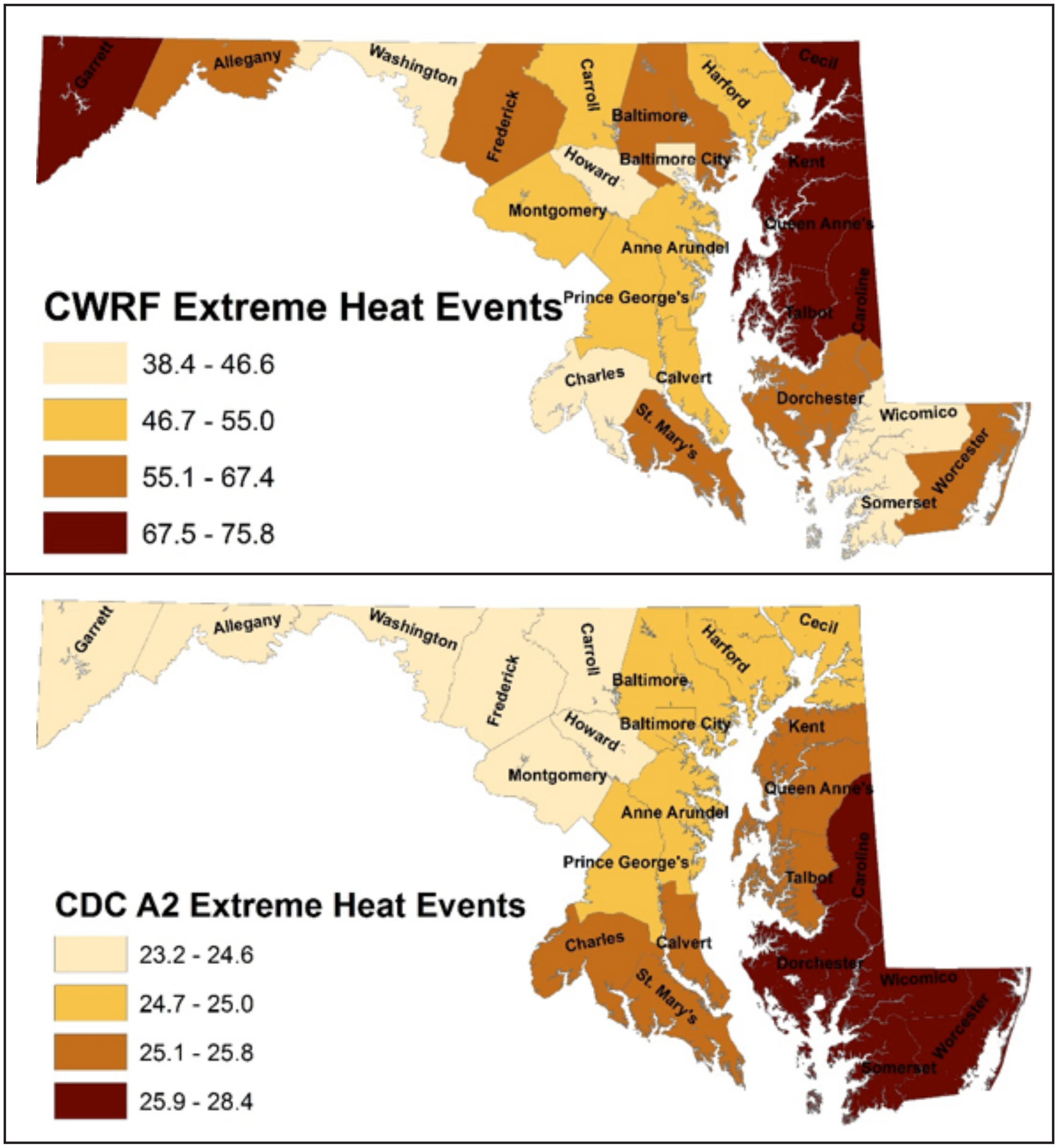
We used the CCSM4-driven CWRF simulation from 1980-2005 as a baseline and computed county-level extreme events for the future decade of 2040 using the projection data (RCP8.5). The methodology we used for actual derivation of the baseline and extreme events for future decades using the CWRF projections was analogous to the ones used with historical data as described in a previous section. Based on this data, extreme heat and precipitation events were calculated using 95^{th} and 98^{th} percentile thresholds.

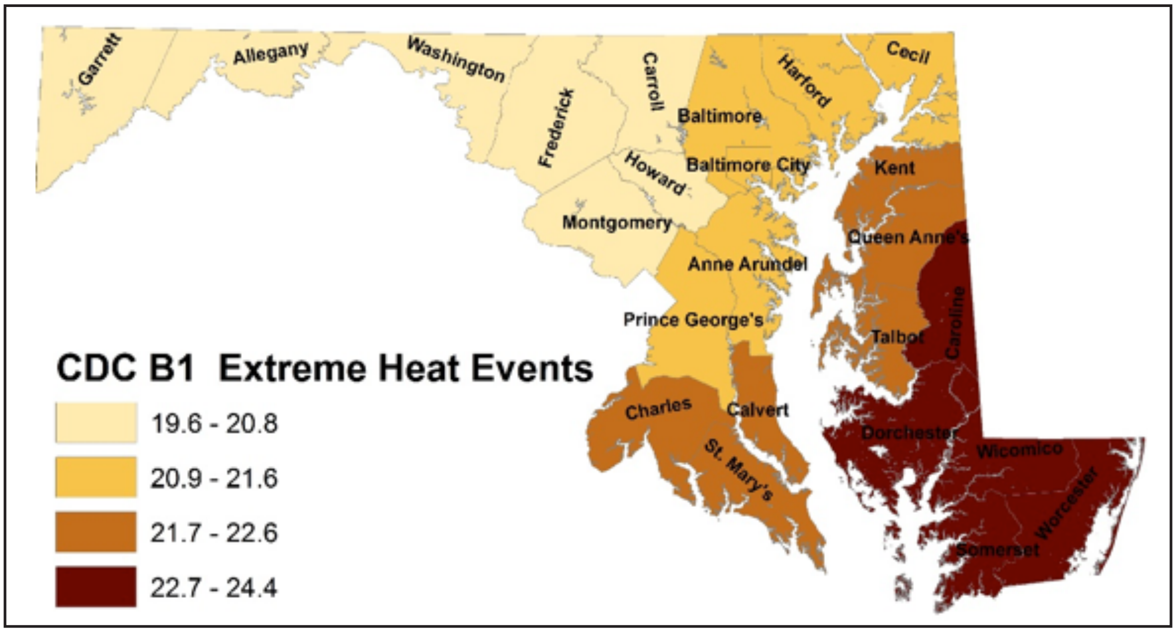
Table 18. Projected number of extreme events for Maryland by Climate Forecast Model.

EXTREME EVENTS	YEAR*	CWRF*□	CWRF	A2ᵃ*	B1ᵃ*
HEAT	2010	33	16	N/A	N/A
	2040	58	34	25	22
PRECIPITATION	2010	38	N/A	N/A	N/A
	2040	41	N/A	N/A	N/A

**2010 events were calculated using 2008-2012 average, and 2040 from 2038-2042 average.*
□Calculated using 95^{th} percentile thresholds, the rest calculated using 98^{th} percentile thresholds.
[a]A2 is the Regional Growth scenario, while B1 is the Service Economy scenario.

Figure 18. Projected number of extreme heat events by county, for the year 2040, based on three Climate Forecast Models.





RELATIONSHIP BETWEEN OBSERVED EXTREME EVENTS AND SELECTED DISEASE BURDEN IN MARYLAND (2000-2012

Definition of Risk

Throughout this document we have given the reader an understanding of how extreme heat and extreme precipitation events have influenced the level of risk for a variety of health outcomes both historically and for future projections. The use of the word "risk" has encompassed many definitions that require clarification with respect to the specific methods utilized for statistical analysis. Change in risk for the assessment of hospitalization due to myocardial infarction and asthma, as well as motor vehicle accidents, specifically refers to the change in odds ratios. Change in risk for the assessments of campylobacteriosis and salmonellosis specifically refer to the change in incident rate ratios. Though for the purposes of this report the overarching interpretations are similar, it is important to note the subtle differences of how the statistical analyses were conducted for these health outcomes as well as the interpretation of the resulting estimates of risk.

Motor Vehicle Accidents

Previous studies have linked poor weather events with motor vehicle accidents.[71] Some factors associated with weather-related events that contribute to hazardous driving conditions include decreased tire-surface friction and greater impairment of driver visibility.[72] An increase in precipitation has been linked with higher frequency of traffic accidents.[73–81] In one Canadian study of mid-sized cities, precipitation on average increased the total number of accidents by 75% and related injuries by about 45%.[82] In addition, higher temperatures have been associated with greater risk of traffic accidents.[83] However, none of the studies have looked at how frequencies of extreme events, which are projected to increase in response to a changing climate, contribute to motor vehicle accidents.

To investigate the relationship between extreme events and risk of motor vehicle accidents, a time-stratified case-crossover design was used to examine associations between both extreme precipitation and extreme heat events and occurrence of a motor vehicle accident event in Maryland between the years 2000 and 2012. Seasonality and road condition were assessed as two factors that may influence the risk of motor vehicle accident.

A total of 1,294,303 unique motor vehicle accident events were observed between January 1, 2000, and December 14, 2012 across Maryland (Table 19). A slightly higher number of accidents occurred during the fall (n=335,893) than during the other seasons. Of the nearly 1.3 million motor vehicle accidents, 27,275 accidents occurred on a road with some type of defect, such as shoulder defects and holes or ruts, or a physical or visual obstruction, but the overwhelming majority of motor vehicle accidents occurred on roads that had no noticeable defects (n=1,229,584).

Myocardial Infarction

We obtained inpatient hospital admission data that encompassed the International Classification of Diseases, Ninth Revision (ICD-9) principal diagnosis code: 410 from the Maryland Department of Health and Mental Hygiene. For this analysis, we defined extreme heat events as days where the maximum daily temperature exceeded the 95th percentile of daily baseline values of county specific maximum temperature values. Statistical analysis employing a time-stratified case-crossover design was used to examine association between extreme heat events during summertime and heart attack hospitalizations in Maryland from 2000 to 2012. There were 32,670 cases of hospitalizations for heart attack during the summer months in Maryland between 2000 and 2012 (Table 21). Overall, the majority of hospitalizations were among those aged 65 or older (18,603 cases; 56.9%) as compared to those aged 18-64

Table 19. Characteristics of motor vehicle accidents in Maryland, Years 2000-2012

CHARACTERISTICS	# OF CASES	% CASES
TOTAL	1,294,303	100
SEASON		
SPRING	319,672	25
SUMMER	318,777	25
FALL	335,893	25
WINTER	319,961	25
ROAD CONDITION		
NO INFORMATION	37,444	3
NO DEFECTS	1,229,584	95
DEFECTS/OBSTRUCTIONS	27,275	2

Table 20. Odds ratios (OR) and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and motor vehicle accidents in Maryland, Years 2000-2012.

VARIABLES	HEAT	PRECIPITAION
	ODDS RATIO (95% CI)	
OVERALL MODEL	1.01 (1.00, 1.02)	1.23 (1.22, 1.24)
SEASON		
SPRING	1.05 (1.03 1.07)	1.20 (1.18, 1.21)
SUMMER	1.09 (1.07, 1.10)	1.24 (1.22, 1.25)
FALL	0.88 (0.86, 0.90)	1.32 (1.31, 1.34)
WINTER	0.97 (0.96, 0.99)	1.13 (1.12, 1.15)
ROAD CONDITION		
NO INFORMATION	1.06 (1.01, 1.12)	1.25 (1.20, 1.29)
NO DEFECTS	1.01 (1.00, 1.02)	1.22 (1.21, 1.23)
DEFECTS/OBSTRUCTIONS	0.91 (0.84, 0.97)	1.46 (1.40, 1.52)

(14,067 cases; 43.1%). Additionally, more males (57.3%) were hospitalized than females (42.7%) and more non-Hispanic whites (68.4%) were hospitalized than non-Hispanic blacks (20.6%).

In general, exposure to summertime extreme heat event was associated with 11% increase in the risk of hospitalization for heart attack in Maryland. The increase in risk of hospitalization was considerably higher among non-Hispanic blacks (27%), compared to non-Hispanic whites (9%)

Asthma

We obtained inpatient hospital admission data that encompassed the International Classification of Diseases, Ninth Revision (ICD-9) principal diagnosis code: 493 from the Maryland Department of Health and Mental Hygiene. Hospitalization admissions included those that spanned the summers (June to August) of January 1st, 2000 to December 14th, 2012 for the entire state of Maryland. For each case record, additional information was extracted including county of residence, age, gender, race/ethnicity, and admission to hospital date. As with hospitalization for heart attack, we used a time-stratified case-crossover design to examine association between extreme heat and precipitation events and hospitalizations for asthma in Maryland from 2000 to 2012.

Summary of Results: From 2000 to 2012, there were 20,776 hospitalizations due to asthma in the summer months in Maryland (Table 23). Results show that exposure to extreme heat event was associated with a 22% increase in risk of hospitalization for asthma in Maryland between 2000 and 2012. Similarly, exposure to extreme precipitation event was associated with an 11% increase in risk of hospitalization for asthma in Maryland for the same time period. Although non-Hispanic blacks have a higher baseline rate of hospitalization for asthma, the

Table 21. Demographic characteristics of hospitalizations for heart attack in Maryland, Years 2000-2012.

CHARACTERISTICS	# OF CASES	% CASES
TOTAL	138,665	100
AGE GROUP		
18 TO 64	58,036	42
65 AND OLDER	80,629	58
GENDER		
FEMALE	59,849	43
MALE	78,812	57
RACE/ETHNICITY		
NON-HISPANIC WHITE	95,555	69
NON-HISPANIC BLACK	28,293	20
HISPANIC	1,632	1
OTHER RACES	5,987	4
UNREPORTED	7,198	5
SEASON		
WINTER	36,511	26
SPRING	35,460	25
SUMMER	32,670	24
FALL	34,024	25

Table 22. Odds ratios (OR) and 95% Confidence Interval (CI) for exposure to extreme heat and risk of hospitalization for heart attack during summer months in Maryland, Years 2000-2012.

VARIABLES	ODDS RATIO (95% CI)
OVERALL MODEL	1.11 (1.05 – 1.17)
GENDER	
FEMALE	1.09 (1.00 – 1.19)
MALE	1.12 (1.05 – 1.21)
AGE	
18 TO 64	1.10 (1.02 – 1.20)
65 AND OLDER	1.11 (1.04 – 1.20)
RACE/ETHNICITY	
NON-HISPANIC WHITE	1.09 (1.02 – 1.16)
NON-HISPANIC BLACK	1.27 (1.12 – 1.44)

Table 23. Demographic characteristics of hospitalizations for asthma in Maryland, Years 2000-2012.

CHARACTERISTICS	# OF CASES	% CASES
TOTAL	115,923	100
AGE GROUP		
UNDER 5	18,043	16
5 TO 17	16,649	14
18 TO 64	59,462	51
65 AND OLDER	21,768	19
GENDER		
FEMALE	70,695	61
MALE	45,226	39
RACE/ETHNICITY		
NON-HISPANIC WHITE	47,151	41
NON-HISPANIC BLACK	58,347	50
HISPANIC	3,047	3
OTHER	3,479	3
UNREPORTED	3,899	3
SEASON		
WINTER	30,436	26
SPRING	31,103	27
SUMMER	20,776	18
FALL	33,608	29

Table 24. Odds ratios and 95% Confidence Interval (CI) for exposure to extreme events and risk of hospitalization for asthma during summer months in Maryland, Years 2000-2012.

VARIABLES	HEAT	PRECIPITATION
	ODDS RATIO (95% CI)	
OVERALL MODEL	1.22 (1.15 – 1.33)	1.11 (1.06 – 1.17)
GENDER		
FEMALE	1.24 (1.13 – 1.35)	1.11 (1.04 –1.18)
MALE	1.22 (1.08 – 1.38)	1.12 (1.04 –1.22)
AGE GROUP		
UNDER 5	1.08 (0.87 – 1.34)	1.20 (1.05 – 1.37)
5 TO 17	1.36 (1.05 – 1.77)	1.11 (0.94 – 1.30)
18 TO 64	1.28 (1.16 – 1.41)	1.11 (1.04 – 1.18)
65 AND OLDER	1.16 (1.00 – 1.35)	1.07 (0.96 – 1.19)
RACE/ETHNICITY		
NON-HISPANIC WHITE	1.33 (1.19 – 1.49)	1.09 (1.01 – 1.18)
NON-HISPANIC BLACK	1.20 (1.08 – 1.33)	1.13 (1.06 – 1.21)
HISPANIC	0.67 (0.41 – 1.09)	1.16 (0.85 – 1.60)

increase in extreme heat-related risk was larger among non-Hispanic whites (33%) compared with non-Hispanic blacks (20%). No significant increased risk was observed among Hispanics.

Salmonellosis and Campylobacteriosis

Salmonella and *Campylobacter* cases reported to the Maryland Foodborne Diseases Active Surveillance Network (2002–2012) were used to investigate how changes in extreme heat and precipitation events may change the disease burden. Demographic data at the individual level were not available, so county level descriptions such as age, race/ethnicity, and gender were obtained from the 2010 Census of Population and Housing.[84] Specifically, data obtained included the county level percentage of 1) people in the age groups <5, 5-17, 18-64, and ≥65; 2) individuals living below the poverty level in 2010; 3) populations of individual races; and 4) gender.

All of the counties in Maryland were grouped as either "coastal" or "non-coastal" counties. The coastal counties are geographically situated in the Maryland coastal zone and the Chesapeake Bay watershed area (Figure 19). The non-coastal counties lie in the Chesapeake Bay watershed but are not situated in the Maryland coastal zone. Low elevation and proximity to the Chesapeake Bay and Atlantic Ocean influence the climate of the eastern region of the State, while varying topography and the Appalachian Mountains influence climate in the western region.[85]

Since exact date of onset was not available, we

Figure 19. Map of regions within Maryland used for analyzing food and waterborne disease risks.

used negative binomial Generalized Estimating Equations (GEE)[86,87] instead of the case-crossover analysis, to investigate the relationship between EPT_{90} and ETT_{95} exceedance events and salmonellosis as well as campylobacteriosis risk separately in all 24 Maryland counties for the 2002 to 2012 time period. First, we ran an overall analysis that included the entire study population, adjusting for potential confounders including poverty status, age, gender, and race. Following this, we ran restricted analyses that focused on specific age groups (<5, 5-17, 18-64, ≥65), race (non-Hispanic white, non-Hispanic black), gender (male, female), season (Spring, Summer, Fall, and Winter) and geographic location (coastal counties, non-coastal counties). We performed all statistical analyses in SAS 9.4 (Cary, NC USA), utilizing the PROC GENMOD command with REPEATED statement for controlling the autocorrelation of repeated measurements within each county.

There were a total of 9,529 culture-confirmed cases of *Salmonella* infections (Table 25) and 4,804 culture-confirmed cases of *Campylobacter* infections reported to the FoodNet program between January 1, 2002 to December 31, 2012 (Table 27). Exposure to extreme heat and precipitation events increased the risk of *Salmonella* infections in Maryland, and this risk was considerably higher among coastal counties compared to non-coastal counties (Table 26). Extreme heat event was not associated with *Campylobacter* infections in Maryland, while extreme precipitation event increased the risk of *Campylobacter* infections only in the coastal counties of Maryland (Table 28).

Table 25. Demographic characteristics of reported salmonellosis cases in Maryland, Years 2002-2012.

CHARACTERISTICS	# OF CASES	% CASES
TOTAL	9,529	100
AGE GROUP		
UNDER 5	2,380	25
5 TO 17	1,661	17
18 TO 64	4,462	47
65 AND OLDER	979	10
UNREPORTED	47	0.5
GENDER		
FEMALE	5,023	53
MALE	4,475	47
UNREPORTED	31	0.3
RACE/ETHNICITY		
NON-HISPANIC WHITE	3,755	39
NON-HISPANIC BLACK	2,509	26
HISPANIC	515	5
OTHER	293	3
UNREPORTED	2,457	26
SEASON		
WINTER	1,377	15
SPRING	1,853	19
SUMMER	3,777	40
FALL	2,520	26

PROJECTION OF DISEASE BURDEN

Future projections of the frequency of extreme heat events at the county-level across Maryland were computed based on the climate projections from the Climate-Weather Research and Forecasting Model (CWRF). CWRF extended the Weather Research and Forecasting model by incorporating more than thousands of alternative physics configurations. The configurations included the interactions between surface, planetary boundary layer, cumulus, microphysics, cloud, aerosol and radiation.[69] The CWRF can have a fine spatial resolution of prediction. County-level estimates were obtained using modeled temperature data that were converted from gridded projections. Furthermore, these data were calculated on an annual basis using a 27-year rolling average. Baseline data used to establish various percentile thresholds were based upon data available from 1979-2005.

Table 26: Incident Rate Ratios (IRR) and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and Salmonella infections in Maryland, Years 2002-2012.

VARIABLES	HEAT	PRECIPITATION
	INCIDENT RATE RATIO (95% CI)	
SEASON		
WINTER	0.96 (0.93 – 1.00)	1.01 (0.97 – 1.05)
SPRING	0.96 (0.93 – 1.00)	1.01 (0.98 – 1.04)
SUMMER	1.05 (1.01 – 1.08)	1.02 (0.99 – 1.05)
FALL	1.00 (0.96 – 1.05)	1.04 (1.02 – 1.06)
REGION		
COASTAL COUNTIES	1.05 (1.02 – 1.08)	1.07 (1.04 – 1.10)
NON-COASTAL COUNTIES	1.02 (0.98 – 1.06)	1.04 (1.02 – 1.05)

Table 27. Demographic characteristics of reported campylobacteriosis cases in Maryland, Years 2002-2012.

CHARACTERISTICS	# OF CASES	% CASES
TOTAL	4,804	100
AGE GROUP		
UNDER 5	513	11
5 TO 17	569	12
18 TO 64	3,184	66
65 AND OLDER	522	11
UNREPORTED	16	0.3
GENDER		
FEMALE	2,213	46
MALE	2,580	54
UNREPORTED	11	0.2
RACE/ETHNICITY		
NON-HISPANIC WHITE	2,426	51
NON-HISPANIC BLACK	407	9
HISPANIC	223	5
OTHER	143	3
UNREPORTED	1,605	33
SEASON		
WINTER	772	16
SPRING	951	20
SUMMER	1,968	41
FALL	1,113	23

Figure 20. Regional campylobacteriosis case rates from 2002 to 2012.

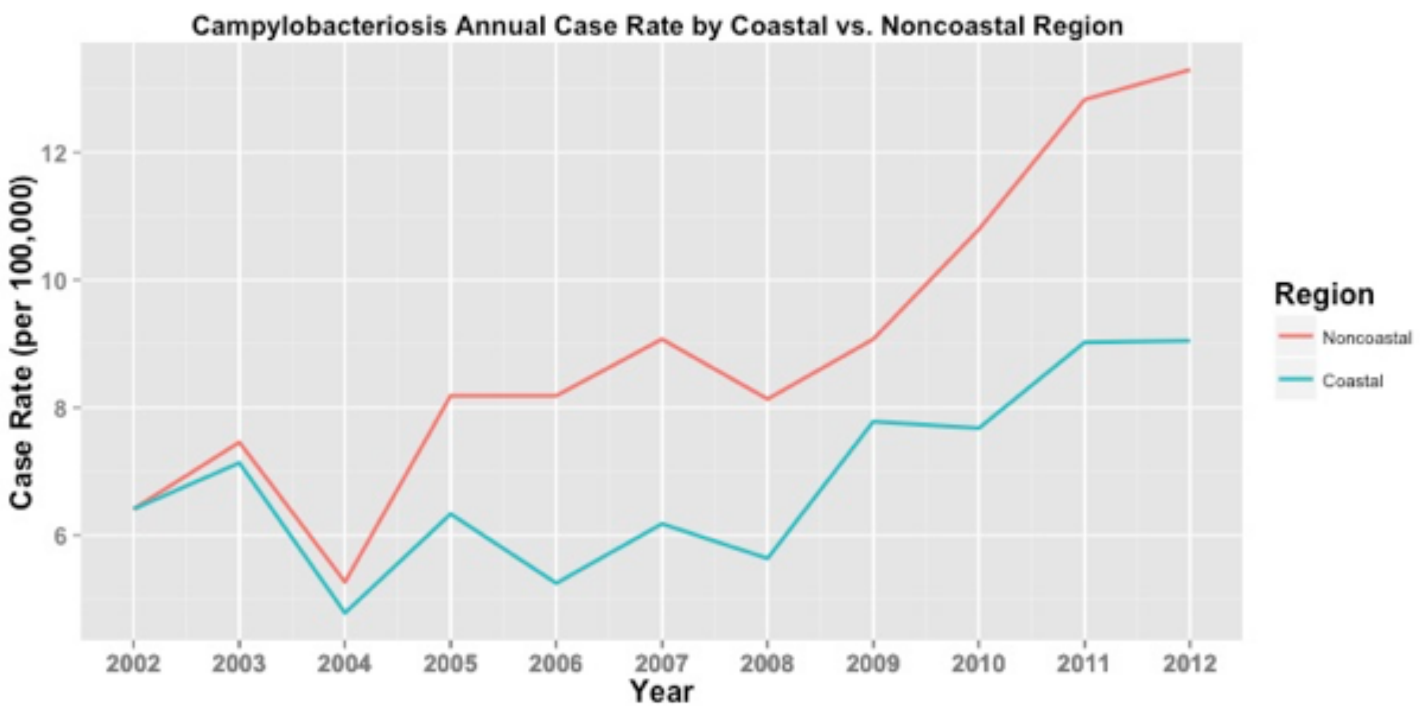


Table 28. Incident Rate Ratios (IRR) and 95% Confidence Interval (CI) for exposure to extreme heat and precipitation events and Campylobacter infections in Maryland, Years 2002-2012.

VARIABLES	HEAT	PRECIPITATION
	INCIDENT RATE RATIO (95% CI)	
SEASON		
WINTER	0.93 (0.90 – 0.96)	0.99 (0.94 – 1.04)
SPRING	0.93 (0.89 –0.98)	1.00 (0.96 – 1.04)
SUMMER	1.01 (0.98 – 1.03)	1.00 (0.98 – 1.02)
FALL	0.96 (0.91 – 1.01)	1.01 (0.98 – 1.04)
REGION		
COASTAL COUNTIES	1.01 (0.98 –1.03)	1.03 (1.01 – 1.05)
NON-COASTAL COUNTIES	0.99 (0.95 –1.03)	1.01 (0.98 – 1.05)

The disease projections for 2040 were done as described previously[88,89] and relied on the following equation:

$$Cases_{2040}=\{[(EHE_{2040}-EHE_{2010})/12\times(ERF_{2010}-1)]+1\}\times DR_{2010}\times(Popu_{2040}/100{,}000)$$

where EHE_{2040}: Frequency of extreme heat events during summer months in 2040s, calculated as average of 2038-2042; EHE_{2010} is frequency of extreme heat events during summer months in 2010s calculated as average of 2008-2012. ERF_{2010}: Exposure-response functions empirically derived for each county and Maryland as a whole using the 2000-2012 heath data. DR: disease rate per 100,000 in 2010; $Popu_{2040}$: Projected population in 2040. It should be noted, however, that for calculating county level projections for *Salmonella* infections, only the statewide incident rate ratio (exposure-response risk estimate) from 2002-2012 was available.