Climate Change and Public Health through the Lens of Rural, Eastern North Carolina

Gregory D. Kearney, Katherine Jones, Ronny A. Bell, Marian Swinker, Thomas R. Allen

BACKGROUND Recognizing that health outcomes are associated with climate threats is important and requires increased attention by health care providers and policymakers. The primary goal of this report is to provide information related to the public health threats of climate change, while identifying climate-sensitive populations primarily in rural, Eastern North Carolina.

METHODS Publicly available data was used to evaluate regional (eg, Eastern, Piedmont, and Western) and county level socio-vulnerability characteristics of population groups in North Carolina, including: percent of persons living in poverty, percent of non-white persons, percent of persons under 18 years living in poverty, percent of elderly people living in poverty, percent of persons with a disability, and number of primary care physicians. One-way ANOVA was used to calculate and compare mean value estimates of population socio-vulnerability variables in Eastern North Carolina with Piedmont and Western regions.

RESULTS Across all regional categories, the eastern part of the state had considerably higher averages than the state for percent of persons living in poverty (17.2%), percent of non-white persons (13.3%), percent of persons under 18 years old living in poverty (24.9%), percent of elderly people living in poverty (10.0%), and percent of persons with a disability (13.3%). Overwhelmingly, more counties in Eastern North Carolina had fewer primary care physicians (per 10,000 persons) than the state average (8.6 per 10,000 persons).

CONCLUSION Eastern North Carolina has a disproportionately higher percent of population groups that are vulnerable to the threats of climate change. The need for health care providers to understand and communicate the challenges faced by rural, vulnerable population groups is of great public health importance. Communicating these health risks to policy makers is of equal importance.

The Intergovernmental Panel on Climate Change (IPCC) reports that the release of carbon dioxide and other greenhouse gases (GHGs) from human activity is at the highest level in history and these gases are contributing to widespread impacts on human health and natural systems [1, 2]. Just over the past century, the release of anthropogenic GHG emissions into the atmosphere, primarily from the burning of fossil fuels, has contributed to increased global land and ocean surface temperatures by an average of 1.5°F with average temperatures projected to increase from 0.5°F to upwards of 8.6°F by 2100 [2]. Rising temperatures of the Earth have led to significant changes in the natural environment, including acidity of oceans, diminished ice and snow, and rising sea levels [1, 2]. Such environmental changes are credited with influencing regional weather patterns, leading to temperature extremes, shifts of climatic zones, heavy precipitation, drought, wildfires, hurricanes, heat waves, and coastal flooding [2, 3].

Vulnerability and Population Groups of Concern

While the influences of weather and climate on human health are complex, the consensus among scientists is that both observed and predicted associations of current climate effects will continue to negatively affect human health and pose new health concerns [1, 2, 4-7]. However, the impacts of climate change across regions and population groups are not homogenous [8]. Some population groups are considered more vulnerable and face greater stressors to both climate-related (ie, direct effects) and non-climate factors (ie, indirect effects). For example, young children, elderly people, people with disabilities, and the poor are more vulnerable to sustained heat events (a direct effect), and social and economic stressors from rising food prices, medicine costs, and higher utility bills for keeping cool in the summer and warm in the winter (indirect effects) [1, 9, 10].

While physical and social impacts of climate-change-induced hurricanes and other severe weather events on urban and wealthy coastal communities have captured a great amount of attention [11], disadvantaged and marginalized populations living in rural areas are also considerably vulnerable [8]. By comparison, people living in rural communities tend to be older, have significantly lower incomes, have less education, suffer more health problems, and are more socially isolated than their urban counterparts [8, 12]. In addition, rural populations are often under-insured, have reduced access to medical care, and lack transportation to essential services [12].

Eastern North Carolina (ENC-41)

The Eastern region of North Carolina (ENC-41, defined as the 41 counties that make up the coastal plain, located east of Interstate 95) is characteristically vulnerable to climate
change threats. First, the area is largely rural, with vastly isolated, climate-sensitive sub-populations that have low access to health care. Second, many counties in the area are highly impoverished with a considerable percent of communities of color and outdoor immigrant workers who live in poor housing. Third, the region historically has had the highest mortality and prevalence rates of discernable health disabilities and highest incidence rates of several major chronic health conditions and diseases in North Carolina [13].

Recent reports of heat-related events among the young, elderly people, and the outdoor workforce are indicators of rising temperatures and vulnerability in North Carolina [14, 15]. For example, from 2008 to 2010, Rhea and colleagues identified a significant correlation between increased temperatures in North Carolina and heat-related illness (HRI) emergency department visits. The highest percentage of heat-related exposures were among people aged 15-18; work-related heat exposures were highest among persons aged 19-45. Older adults were reported more likely to be admitted to the hospital than younger persons [16], suggesting elderly residents are more sensitive and may be less likely to have capabilities to cope with the threat of extreme rising heat temperatures. According to a separate report, from 1992 to 2006, North Carolina had the highest annualized rate of heat-related deaths in the United States, the majority of which occurred within the ENC-41 region [17]. Montz and Allen noted patterns of extreme summer heat across Duplin, Sampson, and Wayne counties, and increased heat-related exposure threats to farmworkers and other marginalized outdoor workers. [18].

**Socio-Vulnerability**

Socio-vulnerability is a term used to describe “socioeconomic and demographic factors that affect a community’s resilience to external stressors from natural or human-caused disasters [19, 20].” Flanagan and colleagues recognized the domains that form the basis of socio-vulnerability as a population’s socioeconomic status (ie, economically disadvantaged); household composition/disability (ie, number of children and older adults); minority status/language (ie, comprising race, ethnicity, and English language proficiency); and housing/transportation (ie, comprising housing structures and vehicle access) [20]. These domains help classify factors for identifying vulnerable population groups and associated climate-related health concerns (see Table 1). A component of the disaster management framework, socio-vulnerability recognizes that the most vulnerable people are those who are more likely to suffer from lack of basic needs, such as financial support, transportation, care, and assistance with daily activities during disasters [20]. Identifying geographical areas where climate-sensitive populations are located can assist in determining where to allocate health resources and targeted climate-adaptation messages and mitigation strategies.

**Purpose**

While a majority of climate change health research has focused on physical and health impacts of coastal and urban populations, little has been published on climate-sensitive population groups living in rural areas of the United States. To our knowledge, no peer-reviewed studies have been published examining population vulnerability to climate change in Eastern North Carolina. The purpose of this study is to report the human health effects associated with climate change while providing an estimate of the percent of socio-vulnerable, climate-sensitive population groups in Eastern North Carolina. We summarize our findings by discussing future challenges and the roles health care and public health professionals play in communicating climate change to their communities.

**Methods**

Following an extensive review of government reports and the published literature, we selected population socio-vulnerability characteristics related to climate change and data variables that were publicly available. Selected socio-vulnerability variables included: percent of individuals with incomes below the federal poverty level, percent of individuals with a disability, percent of individuals (under 18 years) in poverty, percent of elderly people (over 65 years) in poverty, percent of non-white individuals, and number of primary care physicians (per 10,000 population). Socio-vulnerability variables for each of North Carolina’s 100 counties were identified and downloaded from the US Census Bureau and The University of North Carolina at Chapel Hill Sheps Center for Health Services Research websites [21, 22].

| Socio-vulnerable population groups                  | Climate-related vulnerabilities                                                                 |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Elderly people and people with chronic medical conditions, pregnant women | Heat stress, air pollution, water- and food-borne illnesses, vector-borne diseases, mental stress |
| Impoverished and low socioeconomic status           | Heat stress, extreme weather-related events, water- and food-borne illnesses, mental stress       |
| Outdoor workers                                    | Heat stress, air pollution, vector-borne infectious diseases, ultraviolet light exposure           |
| Children and infants in poverty                     | Heat stress, air pollution, water- and food-borne illnesses, vector-borne diseases, malnutrition |
Data Analysis

Data variables were formatted in Microsoft Excel (2007) and uploaded into ArcGIS (ESRI, v.10) to create choropleth maps. The univariate general linear model was used in SPSS (version 24, Chicago, Ill.) to calculate one-way ANOVA. Statistical differences were compared between mean percent of socio-vulnerability variables in ENC-41 counties with Piedmont and Western North Carolina counties. P values < 0.05 were considered statistically significant. Cohen’s d was used to measure effect size.

Results

Vulnerable Population Groups in ENC-41. As shown in Table 2, numerous ENC-41 counties in the region had a considerably higher percent of socio-vulnerable populations compared to the Western and Piedmont regions of North Carolina. As described below, several counties in the east had the highest socio-vulnerable population characteristics in the state.

Percent in poverty. Overall, the average percent of individuals with incomes below poverty level in North Carolina was 17.2%. For the ENC-41 counties that make up the Eastern region, 27 counties were above the state average, 24 counties were above 20%, and 2 counties, Scotland and Robeson, had mean estimates above 30% (32.3 % and 31.7%, respectively).

Percent of elderly people (over 65 years) living in poverty. Overall, a high percentage of counties within the ENC-41 region reported high rates of elderly people in poverty. Twenty-eight counties were above the state average of 10%, with Chowan County reporting 23.6% and Hyde County reporting 20.7%. Other counties in ENC-41 reporting higher averages included Halifax (19.7%), Duplin (19.5%), Robeson (19.1%), and Bertie (19.1%).

Percent of children (under 18 years) living in poverty. A large proportion of counties in the east reported a higher percent of children living in poverty compared to the state average (24.9%). In the ENC-41 region, 31 counties ranked above the state average and 24 counties in the east reported child poverty as above 30%. Six counties—Edgecombe (60.8%), Bertie (64.4%), Northampton (48.3%), Chowan (47.9%), Scotland (46.8%), and Robeson (46.7%)—reported rates above 45%.

Percent of individuals with a disability. On average, 13.3% of individuals in North Carolina reported having any of 6 disabilities (ie, hearing, vision, cognitive, ambulatory, self-care, or independent living). Among counties in the ENC-41 region, 37 counties had a higher percentage of individuals with a disability than the rest of North Carolina; Northampton (25.8%), Jones (24.6%), Halifax (23.6%), Hertford (22.4%), and Washington (21.9%) counties were among those with the highest percentage in the region.

Percent of non-white, minority population. The average percent of non-white population in North Carolina was 30% (see Figure 1); 68% of counties in the ENC-41 were above the state average. Counties reporting non-white populations above 50.0% included: Robeson (70.2%), Bertie (64.4%), Hertford (63.9%), Edgecombe (60.8%), Northampton (60.3%), Halifax (59.4%), Washington (53.4%), Hoke (52.5%), and Scotland (52.4%).

Number of primary care physicians (per 10,000 persons). The ENC-41 region ranked below the rest of North Carolina in the number of primary care providers (per 10,000 population). On average, North Carolina has 8.6 primary care doctors (per 10,000 population), while 18 counties in the ENC-41 region reported fewer than 5 primary care doctors and 10 counties had fewer than 2.8. Two counties, Camden and Tyrrell, had no (0) primary care physicians [22].

Discussion

The results of this study identified that the majority of counties in Eastern North Carolina are rural and have a high percentage of socio-vulnerability population characteristics, which make them highly susceptible to the health impacts of climate change. Rural and remote areas of Eastern North Carolina with the highest percent of impoverishment and socio-vulnerable population groups will continue to experience the greatest impacts. As the planet continues to warm, climate-related threats will increase economic and health challenges for the most vulnerable groups while contributing to existing high poverty and disease burdens in the region.

Rural populations face different challenges related to climate change than urban, more populous areas. This study helps fill a gap in the literature by examining rural populations and climate vulnerability at a regional level. In addition, we advocate for increased public health research at a finer scale that can examine the challenges and other hidden influences of climate-related health among sensitive groups in rural areas. Below we discuss future challenges, communication, and strategies for Eastern North Carolina that support moving this research and issues surrounding climate change in rural areas forward.

Future Challenges

Experts predict that even if effective mitigation strategies were implemented to combat rising temperatures, the current elevated levels of carbon dioxide and GHG emissions would continue to warm the planet several decades into the future [23]. Although future climate threats to parts of the southeastern United States, including rural Eastern North Carolina, are difficult to predict with accuracy, such events are likely to include heavy rains and flooding that will cause
damage to infrastructure (e.g., roadways, stormwater, drinking water, wastewater, and communication systems) [24], agricultural shifts in planting and harvesting times [25], drought, shifting migration patterns of fish, wetland loss, and river flooding [26]. Climate-sensitive groups, such as poor, elderly, young, health-compromised [1, 27], and under-served populations in rural areas need special considerations to avoid being hard hit. For example, several rural “finger” counties in the northeast ENC-41 region currently experience extreme vulnerability including high poverty, with few or no primary care physicians. Based on the evidence from other scientific studies, the trauma associated with extreme

### Table 2

| County       | Poverty (%) | Elderly people in poverty (%) | Children under 18 in poverty (%) | Disability (%) | Non-white (%) | Primary care physicians (N) |
|--------------|-------------|-------------------------------|----------------------------------|----------------|---------------|-----------------------------|
| North Carolina* | 17.2        | 10.0                          | 24.9                             | 13.3           | 30.0          | 8.6                         |
| Beaufort     | 21.14       | 11.5                          | 31.8                             | 18.5           | 30.9          | 6.9                         |
| Bertie       | 23.4        | 19.1                          | 40.4                             | 2.0            | 64.4          | 2.4                         |
| Bladen       | 25.8        | 17.5                          | 37.4                             | 21.4           | 42.9          | 4.8                         |
| Brunswick    | 16.6        | 5.7                           | 26.3                             | 16.1           | 15.4          | 5.0                         |
| Camden       | 6.0         | 6.9                           | 8.3                              | 15.4           | 16.1          | 0.0                         |
| Carteret     | 14.4        | 7.2                           | 23.3                             | 18.1           | 8.9           | 6.1                         |
| Chowan       | 29.0        | 23.6                          | 47.9                             | 17.2           | 37.2          | 8.8                         |
| Cumberland   | 25.0        | 13.4                          | 36.1                             | 20.3           | 37.5          | 5.9                         |
| Craven       | 16.6        | 8.7                           | 26.6                             | 17.7           | 28.0          | 8.3                         |
| Dare         | 8.8         | 4.9                           | 13.5                             | 14.3           | 5.9           | 8.2                         |
| Duplin       | 26.3        | 19.5                          | 39.4                             | 16.2           | 41.8          | 2.7                         |
| Edgecombe    | 25.2        | 16.4                          | 42.4                             | 17.8           | 60.8          | 4.9                         |
| Gates        | 19.6        | 12.9                          | 35.0                             | 16.1           | 35.1          | 0.8                         |
| Greene       | 23.3        | 17.7                          | 37.5                             | 16.1           | 48.4          | 5.2                         |
| Halifax      | 27.4        | 19.7                          | 39.4                             | 23.6           | 59.4          | 6.5                         |
| Harnett      | 17.2        | 12.5                          | 22.2                             | 13.5           | 29.5          | 4.3                         |
| Hertford     | 26.1        | 18.3                          | 39.1                             | 22.4           | 63.9          | 7.3                         |
| Hoke         | 22.9        | 18.3                          | 30.9                             | 13.7           | 52.5          | 2.2                         |
| Hyde         | 25.6        | 20.7                          | 36.5                             | 18.8           | 35.2          | 1.7                         |
| Johnston     | 17.2        | 10.7                          | 24.7                             | 12.2           | 24.2          | 3.9                         |
| Jones        | 16.7        | 9.4                           | 27.0                             | 24.6           | 35.8          | 9.5                         |
| Lenoir       | 23.7        | 15.2                          | 37.2                             | 20.5           | 45.9          | 7.1                         |
| Martin       | 23.2        | 18.7                          | 36.1                             | 20.2           | 46.3          | 5.5                         |
| Nash         | 17.1        | 14.3                          | 23.2                             | 14.9           | 43.2          | 7.5                         |
| New Hanover  | 16.9        | 6.5                           | 23.0                             | 12.5           | 19.2          | 11.9                        |
| Northampton  | 26.3        | 14.3                          | 48.3                             | 25.0           | 60.3          | 2.4                         |
| Onslow       | 15.2        | 9.7                           | 20.6                             | 14.1           | 22.6          | 4.2                         |
| Pamlico      | 13.8        | 6.7                           | 27.2                             | 20.0           | 22.6          | 3.1                         |
| Pasquotank   | 18.4        | 8.8                           | 26.9                             | 15.1           | 42.0          | 9.4                         |
| Pender       | 19.3        | 13.4                          | 27.9                             | 16.8           | 22.4          | 2.9                         |
| Perquimans   | 20.2        | 9.8                           | 31.0                             | 19.6           | 27.0          | 1.5                         |
| Pitt         | 24.3        | 13.6                          | 26.1                             | 12.0           | 39.8          | 14.8                        |
| Robeson      | 31.7        | 19.1                          | 46.7                             | 17.4           | 70.2          | 6.1                         |
| Sampson      | 22.8        | 15.8                          | 22.9                             | 17.7           | 42.1          | 5.8                         |
| Scotland     | 32.3        | 13.2                          | 46.8                             | 21.8           | 52.4          | 9.7                         |
| Tyrrell      | 20.8        | 16.3                          | 35.7                             | 16.5           | 44.7          | 0.0                         |
| Washington   | 23.7        | 11.3                          | 37.9                             | 21.9           | 53.4          | 3.9                         |
| Wayne        | 22.1        | 11.2                          | 34.4                             | 15.2           | 39.7          | 6.2                         |
| Wilson       | 23.2        | 11.2                          | 37.8                             | 15.3           | 47.2          | 6.0                         |

*Denotes percent average of all NC counties (N = 100)
Source: Percent of individuals with a disability (ACS, 2009-2013)
Percent of individuals with incomes below poverty (2009-2013, ACS)
Percent living with a family whose income is below poverty (2009-2013, ACS)
Includes black, Asian, American Indian, and other non-white races (US Census, 2010)
Number of physicians per 10,000 persons (UNC, Sheps Center, 2013)
weather and increasingly warmer temperatures for Eastern North Carolina is likely to increase emergency department visits, including for HRI, respiratory problems (eg, asthma) from poor air quality and longer pollen seasons, injuries and mental health concerns from severe weather, and increased prevalence of vector- and water-borne diseases [2]. This poses serious challenges for rural populations in counties that have limited public health services such as mosquito control, environmental health, or a primary care clinic. Rural nursing homes that may not be able to provide water or electric services when power outages occur pose added concerns. Rural populations that are physically isolated and suffer home damage may have to wait long periods without basic repair services, or may face impassable roads from flooding, as with Hurricanes Floyd [28] and Matthew [29].

The physical geography of the coastal plain of North Carolina also poses evolving threats to human health beyond the direct effects of increased extreme heat and coastal storms. For instance, flooding will further stress fresh water supplies, exacerbate salinization of shallow coastal aquifers, and potentially degrade the effectiveness of on-site sewage (septic) disposal systems. Concomitantly, the increasing strength of tropical storms and heavy rainfall in a longer, hotter summer period could amplify stormwater runoff and nutrient export into many of the estuaries in the coastal plains. This loading, in turn, can contribute to heightened risks of water pollution, algal blooms, hypoxia, fish kills, contaminants, and pathogens (eg, *Escherichia coli*, *Vibrio vulnificus*). Under climate model projections, relative sea level rise in coastal North Carolina is also apt to accelerate, such that mosquito habitats expand with wetlands migrating landward and upward into the more isolated rural areas. Wetter summers may also see an increase in mosquito- and other vector-borne diseases (eg, West Nile Virus, Lyme disease, Zika, and Dengue). Storm surges, elevated by sea level rise, threaten water supplies and centralized wastewater infrastructure during storm disasters, disrupting potable water and spilling untreated wastewater.

**Communicating Climate Change and Health**

There is a paucity of studies examining rural populations and their attitudes toward climate change in the United States. Among the general population, it has been reported that the perception of disagreement among scientists is credited for creating continuous skepticism and doubt about climate change [30]. Nevertheless, recent polls indicate Americans may have turned the corner and are now more favorable toward accepting that climate change is actually occurring. A national Gallup poll conducted in March 2016 (N = 1,109) indicated that 64% of American adults worried a “great deal” or a “fair amount” about global warming, an increase from 55% in the previous year [31]. In another public opinion poll conducted by researchers at Yale (2014), an estimated 63% percent (about 6/10) of adults in the United States “think global warming is happening.” In the same opinion poll, North Carolina ranked similarly to the national average at 62% [32]; opinion estimates at the county level indicated slightly higher percentages (61-64%) among North Carolina coastal counties, but somewhat lower (56-62%) among many rural counties in the Eastern part of the state [32].

One source suggests that getting rural versus urban communities engaged in discussions on climate policy is challenging not only because of long-standing political obstacles, but also for geographic, cultural, and economic reasons [33]. To help influence decision-making in rural areas, local communication strategies could include increased social media campaigns on the economic benefits of switching to alternative energy sources, raising climate literacy education in school classrooms, and advocacy from health care providers to communities on the health benefits of climate-friendly activities (eg, reducing meat consumption, walking instead of driving).

Although acceptance of climate change appears to be increasing, the level of public engagement in the United States with climate change appears to be lacking [34]. Kasperson and colleagues wrote that one of the difficulties
Different regions face different climate change challenges. Crimmins and colleagues noted that effective adaptation measures are closely tied to local conditions and social networks [1]. Campbell-Lendrum and colleagues pointed out that the potential health impacts of climate change can be avoided through a combination of strengthening key health system functions and targeting improvements in the management of specific risks [39]. For example, health vulnerability and adaptation assessments, or resiliency plans, are valuable tools for considering which population groups are most vulnerable and specifying interventions [39]. Low-lying coastal communities including Miami Beach [40] and the City of Portsmouth, VA [41], have been leading efforts to adapt and implement strategies for resiliency planning, such as building resilient infrastructure. A website to help people find information and guidance to build climate resilience is available through the US Climate Resilience Toolkit (https://toolkit.climate.gov/).

Limitations

Although this work represents an ecological study design approach for identifying populations at risk, the results should be interpreted with caution. Climate change is dynamic across regions; adaptation and vulnerability of population groups vary considerably and may not be generalizable. Also, Lal and colleagues pointed out that 2 of the difficulties with analyzing the impacts of climate change on rural communities are the lack of separation between defining rural and urban areas and the variation among climate scenarios [8]. These types of considerations should be taken into account for future studies, particularly when examining a more granular level unit of analysis (eg, census tract level).

Conclusion

Serious efforts are needed to engage communities in environmentally sustainable practices that promote efforts to reduce the threats of carbon emissions and GHGs. Policy decisions made today at global and local levels influence the fate of our environment and health and shape how future generations will live their lives. Regardless of political lead-

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**TABLE 3.**
General Linear Model of Socio-Vulnerability Characteristics between ENC-41 Counties and Piedmont/Western North Carolina Counties (N=100)

| Socio-vulnerability characteristic | ENC-41 counties (N = 41) Mean (%) | SE Lower | SE Upper | Piedmont and Western counties (N = 59) Mean (%) | SE Lower | SE Upper | F | P |
|-----------------------------------|-----------------------------------|----------|----------|-----------------------------------------------|----------|----------|---|---|
| Individuals with a disability     | 17.48 0.62 16.26 18.71 15.78 0.51 | 14.76 16.80 4.47 .037 |        |                                              |          |          |   |   |
| Individuals w/income below poverty| 20.87 0.77 19.35 22.39 18.76 0.64 | 17.49 20.02 4.49 .037 |        |                                              |          |          |   |   |
| Under 18 and living in poverty    | 31.82 1.25 29.35 34.28 27.24 1.04 | 27.24 25.12 7.98 .010 |        |                                              |          |          |   |   |
| Elderly people (over 65) in poverty | 13.11 0.54 11.88 14.33 10.80 0.51 | 9.78 11.82 8.23 .010 |        |                                              |          |          |   |   |
| Non-white                         | 37.23 2.49 32.29 42.18 20.31 2.01 | 16.19 24.43 27.26 .001 |        |                                              |          |          |   |   |

Source. One-way ANOVA
Percent of individuals with a disability (ACS, 2009-2013)
Percent of individuals with incomes below poverty (2009-2013, ACS)
Percent living with a family whose income is below poverty (2009-2013, ACS)
Includes black, Asian, American Indian, and other non-white races (US Census, 2010)
Note. The mean number of primary care physicians in the ENC region was 5.5, (per 10,000 population), SE, 0.57, 95% CI [4.31-6.59]; and 7.4 (per 10,000 population) SE, 0.48, 95% CI [6.44-8.34], in the piedmont and western counties. Number of physicians per 10,000 population (UNC, Sheps Center, 2013)
ership, North Carolina should increase efforts to be a leader in environmental stewardship and clean energy. Movements toward alternative, renewable energy development; sustainable communities with less reliance on fossil fuels; and innovation and tax credits to preserve and protect our natural resources and human health are all achievable goals for our state. Concerned efforts by health care providers, public health professionals, and researchers to communicate the health impacts of climate change can ensure our policymakers and citizens in North Carolina are well-informed to achieve these goals [9]. Sophisticated predictive modeling can provide statistical estimates of climate-related health outcomes, but more hands-on research and monitoring of populations living in rural areas are needed to measure the physical and mental health impacts of climate change. An increased awareness of this important issue is needed to influence decision-making; to shape healthier, more climate-resilient communities; and to protect climate-sensitive populations in Eastern North Carolina.

Gregory D. Kearney, DrPH, MPH associate professor, East Carolina University, Brody School of Medicine, Department of Public Health, Greenville, North Carolina.

Katherine Jones, PhD social research specialist, East Carolina University, Brody School of Medicine, Department of Public Health, Greenville, North Carolina.

Ronny A. Bell, PhD, MS professor and chair, East Carolina University, Brody School of Medicine, Department of Public Health, Greenville, North Carolina.

Marrian Swinker, MD, MPH, FACOEM professor, Brody School of Medicine, Department of Family Medicine, Greenville, North Carolina.

Thomas R. Allen, PhD associate professor, Old Dominion University, Department of Political Science and Geography, Norfolk, Virginia.

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References
1. Crimmins A, Balbus J, Gamble JL, et al. The impacts of climate change on human health in the United States: a scientific assessment. https://s3.amazonaws.com/ClimateHealth2016/low/ClimateHealth2016_FullReport_small.pdf. Published 2016. Accessed October 13, 2017.
2. Climate Change 2014 Synthesis Report Summary for Policymakers. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf. Accessed September 23, 2017.
3. US Global Change Research Program. Climate Change Impacts the United States. http://www.globalchange.gov/ncac2014/low/NCAS3_Climate_Impacts_In_the_UnitedStates.pdf. Published August 18, 2014. Revised October 2014. Accessed September 23, 2017.
4. Brownstein JS, Holford TR, Fish D. Effect of climate change on Lyme disease risk in North America. EcoHealth. 2005;2(1):38-46.
5. Caminade C, Kovats S, Rocklov J, et al. Impact of climate change on global malaria distribution. Proc Natl Acad Sci U S A. 2014;111(9):3286-3291.
6. D’Amato G, Holgate ST, Pawankar R, et al. Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the world allergy organization. World Allergy Organ J. 2015;8(1):25.
7. Greenough G, McGeehin M, Bernard SM, Trtan J, Riad J, Engelberg D. The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. Environ Health Perspect. 2001;109(Suppl 2):191-198.
8. Lal P, Alavalapati J, Mercer E. Socio-economic impacts of climate change on rural United States. Mitig Adapt Strateg Glob Change. 2011;16(6):819-844.
9. Crowley RA, Health and Public Policy Committee of the American College of Physicians. Climate change and health: a position paper of the American college of physicians. Ann Intern Med. 2016;164(9):608-610.
10. Dasgupta P, Morton MF, Dodman D, Karapinar B, et al. Rural Areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ, et al., eds. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY: Cambridge University Press; 2014:613-657.
11. Dow K, Downing T. The Atlas of Climate Change: Mapping the World’s Greatest Challenge. Berkeley, CA: University of California Press; 2007.
12. Agency for Healthcare Research and Quality. 2014 National Healthcare Quality and Disparities Report: Chartbook on Rural Health Care. https://www.ahrq.gov/sites/default/files/wysiwyg/research/findings/nhqrdr/2014chartbooks/ruralhealth/2014nhqrdr-ruralhealth.pdf. Published August 2015. Accessed October 23, 2017.
13. Center for Health Systems Research and Development, East Carolina University. Trends and disparities in mortality in eastern North Carolina (ENC41): Total deaths, premature deaths, and deaths for ten leading causes, 1979-2012. https://www.ecu.edu/cs/dhs/chrhd/HealthIndicators/upload/0815_Trends_and_Disparities_in_Mortality_in_ENC41_1979_2012.pdf. Published 2014. Accessed October 13, 2017.
14. Harduar Morano L, Bunn TL, Lackovic M, et al. Occupational heat-related illness emergency department visits and inpatient hospitalizations in the southeastern region, 2007-2011. Am J Ind Med. 2015;58(10):1114-1125.
15. Luginbuhl RC, Jackson LL, Castillo DN, Loring KA. Heat-related deaths among crop workers-United States, 1992-2006. MMWR. 2008;57(24):649-653.
16. Rhea S, Ising A, Fleischauer AT, Deyneka L, Vaughan-Batten H, Waller A. Using near real-time morbidity data to identify heat-related illness prevention strategies in North Carolina. J Community Health. 2012;37(2):495-500.
17. Arbory S, Jacklitsch B, Farquah O, et al. Heat illness and death among workers - United States, 2012-2013. MMWR. 2014;63(31):661-665.
18. Montz BE, Allen TR, Monitz GI. Systemic trends in disaster vulnerability: migrant and seasonal farm workers in North Carolina, Risk, Hazard, Crisis in Public Policy. 2011(2):1-17.
19. Socio vulnerability index for the United States. Hazards and Vulnerability Research Institute. University of South Carolina website. http://artsandsciences.sc.edu/geog/hvri/. Updated October 2013. Accessed August 15, 2016.
20. Flanagan BE, Gregory EW, Hallisey EJ, Heitgerd JL, Lewis B. A social vulnerability index for disaster management. J Homeland Security Emerg Manage. 2003;8(1):Article 3.
21. United States Census Bureau. Summary file: 2009-2013 American Community Survey. 2010 Census Data. United States Census Bureau website. https://www.census.gov/programs-surveys/acs/. Accessed June 13, 2016.
22. Cecil G, Sheps Center for Health Services Research. North Carolina Health Professions Data System. Sheps Center website. http://www.shpscenter.unc.edu/. Updated October 23, 2017.
23. Patz JA, Engelberg D, Last J. The effects of changing weather on public health. Annu Rev Public Health. 2000;21:271-307.
24. US Department of Transportation. Transportation and Climate Change Clearinghouse. US DOT website. https://www.transportation.gov/. Updated March 9, 2017. Accessed October 25, 2017.
25. Kunkel KE, Easterling DR, Hubbard K, Redmond K. Temporal variations in frost-free season in the United States, 1895-2000. Geophysical Research Letters. 2004;31(3).
26. Ingram K, Dow K, Carter L, Anderson J. Climate of the southeast region, 2007-2011. Am J Ind Med. 2015;58(10):1114-1125.
entific assessment. US Global Change Research Program website. https://health2016.globalchange.gov/. Published 2016. Accessed October 23, 2017.

28. Curry MD, Mansfield CJ, Leonardo KD. Health and social problems of a primary care clinic population after a disaster. The Hurricane Floyd flood. N C Med J. 2001;62(2):99-102.

29. Ogburn T. Major North Carolina roads closed two weeks after Hurricane Matthew. News and Observer. October 21, 2016.

30. Patz JA, McGeehin MA, Bernard SM, et al. The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the US national assessment. Environ Health Perspect. 2000;108(4):367-376.

31. Saad L, Jones JM. US concerns about global warming at eight-year high. GALLUP website. http://www.gallup.com/poll/190010/concern-global-warming-eight-year-high.aspx. Updated March 2-6, 2016. Accessed August 12, 2016.

32. Yale Climate Opinion Maps. Yale Program on Climate Change Communication website. http://climatecommunication.yale.edu/about/projects/yale-climate-opinion-maps/. Updated 2014. Accessed October 2, 2016.

33. Claussen A. Why rural communities need to talk about climate change. BillMoyers.com. https://billmoyers.com/story/climate-democracy-rural-communities/. Published May 19, 2016. Accessed October 13, 2017.

34. Nisbet MC. Communicating climate change: why frames matter for public engagement. Environment: Sci Policy Sustainable Dev. 2009;51(2):12-23.

35. Kasperon JX, Kasperon KR. Social Contours of Risk: Volume 1: Publics, Risk Communication & the Social Amplification of Risk. London, England: Cromwell Press Ltd; 2005.

36. Abelsohn A, Rachlis V, Vakil C. Climate change: should family physicians and family medicine organizations pay attention? Can Fam Physician. 2013;59(5):462-466.

37. The Lancet. The health benefits of tackling climate change: an executive summary for the Lancet series. London, UK: The Lancet; 2017.

38. Kravchenko J, Akushevich I, Abernethy AP, Holman S, Ross Jr WG, Lyerly HK. Long-term dynamics of death rates of emphysema, asthma, and pneumonia and improving air quality. Int J Chron Obstruct Pulmon Dis. 2014;9(1):613-627.

39. Campbell-Lendrum D, Guillemot J, Ebi K. Climate and Health Vulnerability Assessments: A Practical Approach. In: Luber G, Lemery J, eds. Global Climate Change and Human Health. First ed. USA: Jossey-Bass; 2015:363.

40. Resilient Miami. Urban Impact Lab website. http://www.urbanimpactlab.com/resilient-miami-1/. Accessed January 31, 2016.

41. Norfolk: Resilient city. City of Norfolk website. https://www.norfolk.gov/resilience. Accessed February 1, 2016.