Occupational & Environmental Epidemiology

North Carolina Climate-Related Health Indicators: Cancer

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I. Overview

Cancer is a broad group of diseases sharing the common characteristic of abnormal cell division and subsequent spread through the body's tissues. More than 500,000 people die from cancer in the United States each year, making cancer the second most common cause of death behind heart disease.[1]

Cancer development may be influenced by intrinsic factors such as age and genetics as well as extrinsic factors such as environmental contaminants and pathogens. Climate change has the potential to influence cancer development by altering exposure patterns to extrinsic factors both directly through environmental changes and indirectly through climate change mitigation activities. Direct influences of climate on cancer risk may include increases in ultraviolet radiation exposure, temperature-related increases in evaporation and volatilization of chemicals, water contamination related to intensification of the hydrological cycle (e.g., floods, heavy rains) or the rise in sea levels associated with coastal industry and waste infrastructure. Indirect influences of climate change through mitigation activities may also influence cancer risk. For instance, reduced fossil fuel combustion and electric power generation will likely reduce airborne concentrations of several air pollutants linked to cancer development, especially lung cancer. Conversely, alternative energy generation may introduce new sources of chemicals and other risks.[2]

According to the National Institute of Environmental Health Sciences (NIEHS) report, *A Human Health Perspective on Climate Change*, there is currently insufficient information to predict how climate change may affect these various types of exposures, or how these exposures may influence cancer incidence rates.[3] Nonetheless, documenting current climate-related cancer trends in North Carolina will provide a baseline for future comparisons. As such, this report

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[1] Hoyert DL, Xu JQ. Deaths: Preliminary data for 2011. National vital statistics reports; vol 61 no 6. Hyattsville, MD: National Center for Health Statistics. 2012. Accessed http://www.cdc.gov/nchs/data/nvsr/nvsr61/nvsr61_06.pdf 12 Mar 2013.

[2] Portier CJ et al 2010. A Human Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272. Accessed www.niehs.nih.gov/climatereport 12 Feb 2013.

[3] Portier CJ et al 2010. A Human Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272. Accessed www.niehs.nih.gov/climatereport 12 Feb 2013.

presents information on rates of high ultraviolet days, high temperature days, non-melanoma skin cancer, and colorectal cancer for North Carolina.

II. Environmental indicators

1. High ultraviolet (UV) days

Sun exposure is dangerous to human health because of non-ionizing ultraviolet (UV) radiation, which is an invisible type of light given off by the sun's rays and by artificial sources such as tanning beds. Ultraviolet radiation light directly damages human cells and is a primary risk factor for skin cancer and can contribute to cataracts in exposed persons.[4,5] In addition, UV radiation exposure may exacerbate the toxicity of exposures to other environmental toxins such as polyaromatic hydrocarbons which can damage DNA.[6,7] Conversely, sun exposure is important for vitamin D circulation, which is an important preventive factor for reducing colorectal cancer risk.[8] If high UV days become more frequent with climate change, North Carolina may experience different trends in melanoma skin cancer and colorectal cancer incidence rates in the future.

The State Climate Office CRONOS database collects daily solar radiation data from four North Carolina monitoring sites, where solar radiation sensors are mounted on a weather tower at a height of two meters above the ground.[9] Figure 1 presents the monthly averages of daily maximum 2-meter solar radiation (collected four times a year) from these four North Carolina climate monitoring sites from October 2000 to June 2011. The highest solar radiation values among these four sites were recorded in Ashe County.

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[4] Tucker MA. 2009. Melanoma Epidemiology. Hematology Oncology Clinics of North America (23): 383-395.

[5] National Institutes of Health, National Eye Institute. Facts about cataract. Accessed http://www.nei.nih.gov/health/cataract/cataract_facts.asp#2a 15 Mar 2013.

[6] Dong, S., Hwang, H. M., Shi, X., Holloway, L., & Yu, H. (2000). UVA-induced DNA single-strand cleavage by 1-hydroxypyrene and formation of covalent adducts between DNA and 1-hydroxypyrene. *Chemical research in toxicology*,*13*(7), 585-593.

[7] Toyooka, T., & Ibuki, Y. (2006). New method for testing phototoxicity of polycyclic aromatic hydrocarbons. *Environmental science & technology*,*40*(11), 3603-3608.

[8] Garland, C. F., Gorham, E. D., Mohr, S. B., & Garland, F. C. (2009). Vitamin D for cancer prevention: global perspective. *Annals of epidemiology*, *19*(7), 468-483.

[9] State Climate Office of North Carolina. CRONOS Database. Accessed http://www.nc-climate.ncsu.edu/cronos 14 Feb 2013.

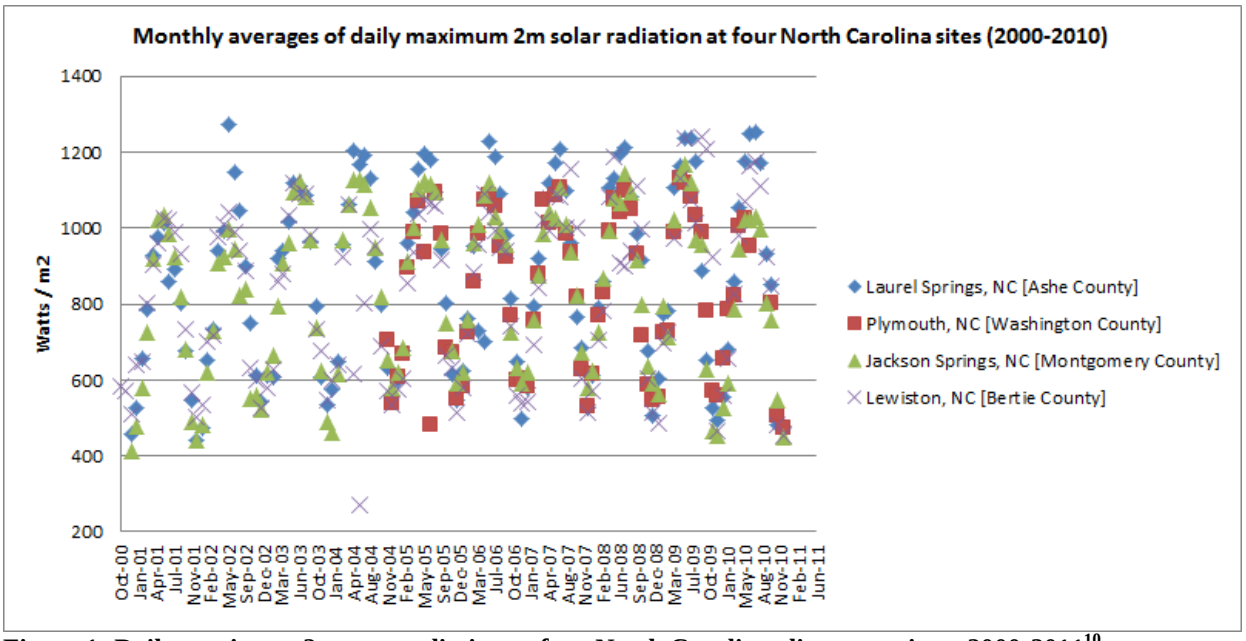

Figure 1: Daily maximum 2-meter radiation at four North Carolina climate stations, 2000-2011[10]

2. High temperature days

High temperature days are associated with greater risks for cancer for several reasons. First, people are more likely to be outdoors during the day and during warmer seasons when temperatures are higher, and therefore are more likely to be exposed to ultraviolet radiation from the sun. In addition, a warming climate will lead to longer growing seasons and therefore, greater occupational sun exposure among outdoor workers such as farmers, which can put them at greater risk for skin cancer.[11,12] Finally, high temperatures are known to promote chemical volatilization, which means that under high temperature conditions, certain toxic chemicals easily convert from a liquid state (such as waste water) to a gas state and therefore can travel to

[10] State Climate Office of North Carolina. CRONOS Database. Accessed http://www.nc-climate.ncsu.edu/cronos 14 Feb 2013.

[11] van der Leun, J. C., & de Gruijl, F. R. (2002). Climate change and skin cancer. *Photochem. Photobiol. Sci.*, *1*(5), 324-326.

[12] Diffey, B. (2003). Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. *Physics in medicine and biology*, *49*(1), R1.

more distant places. As a result, new populations could be exposed to carcinogenic compounds in the air.[13]

According to climate monitoring at New Hanover County Airport (KILM), which is located in the southeastern region of North Carolina, both the number of "hot" days (>100°F) and the "extremely hot" days (>115°F) as measured by the heat index[14] have increased over the past decade (Figure 2).[15] While these New Hanover data reflect only one monitor among hundreds of climate monitoring sites across the state, the southeastern corner of the state is illustrative of the rise of potentially high temperatures for North Carolina. Current global climate models project that average temperatures in the southeastern region of the United States will increase with more frequent extreme heat waves. Some models estimate that the Southeast will experience three times as many days over 90°F over the next 100 years.[16] More frequent high temperature days as a result of climate change could potentially result in higher cancer incidence rates in North Carolina.

[13] Burke, K. E., & Wei, H. (2009). Synergistic damage by UVA radiation and pollutants. *Toxicology and Industrial Health*, *25*(4-5), 219-224.

[14] Heat index is a compound measure assessing the "apparent temperature" experienced by human skin, determined by combining both temperature and relative humidity on a particular day in a mathematical model. For more information, visit: http://www.nc-climate.ncsu.edu/climate/heat_index_climatology.php

[15] State Climate Office of North Carolina. CRONOS Database: Heat index climatology. Accessed http://www.nc-climate.ncsu.edu/climate/heat_index_climatology.php 14 Feb 2013.

[16] North Carolina State Climate Office. Climate Education for Health: Effects of Climate Change on the Southeast. Accessed http://www.nc-climate.ncsu.edu/edu/health/health.climatechange.SE 14 Feb 2013.

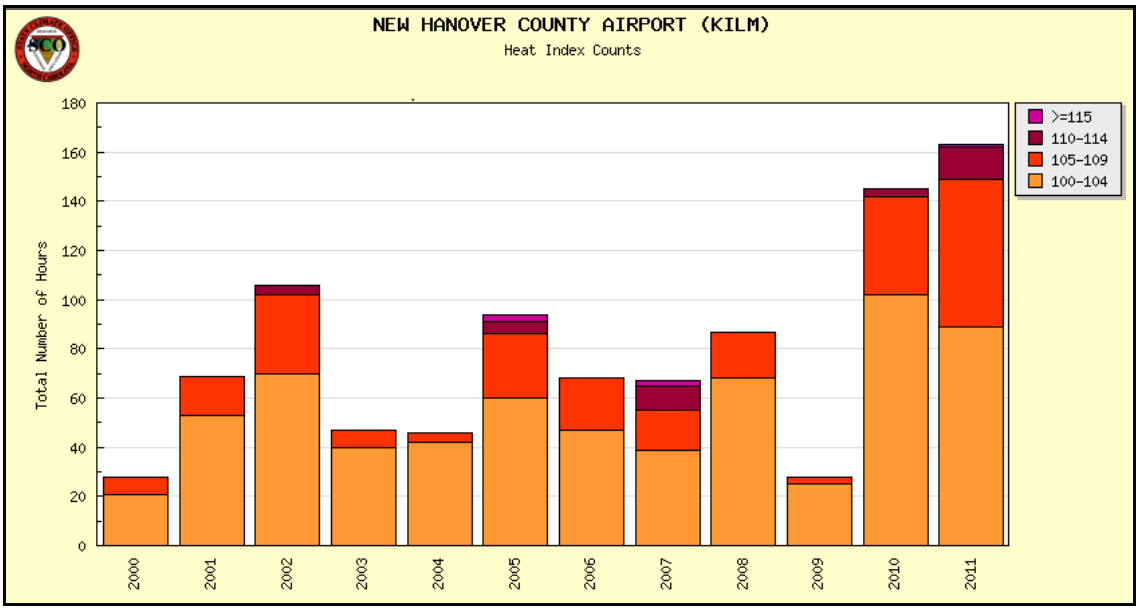

Figure 2: Heat index counts for New Hanover County Airport, New Hanover County, NC, 2000-2011[17]

III. Health indicators

3. Skin cancer

Skin cancer is a general term referring to a number of different cancers that occur in skin cells. In the United States, skin cancer accounts for almost half of all reported cancers, making it the most common type of cancer.[18] Some types include melanoma, basal cell carcinoma and squamous cell carcinoma.

While the biggest environmental risk factor for skin cancer is exposure to UV radiation, behavioral factors can also increase one's risk for skin cancer. Research has shown that spending time outdoors between the hours of 10:00 a.m. and 4:00 p.m. can increase one's risk for skin cancer. Therefore, occupational hazards exist for certain populations, such as agricultural workers, who spend a majority of their day outdoors.[19]

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[17] State Climate Office of North Carolina. CRONOS Database. Accessed http://www.nc-climate.ncsu.edu/cronos 14 Feb 2013.

[18] American Cancer Society. Skin Cancer Facts. Accessed http://www.cancer.org/cancer/cancercauses/sunanduvexposure/skin-cancer-facts 15 Mar 2013.

[19] Glanz, K., Buller, D. B., & Saraiya, M. (2007). Reducing ultraviolet radiation exposure among outdoor workers: State of the evidence and recommendations. *Environ Health*, *6*(22), 1-11.

In light of this health disparity, researchers in eastern North Carolina conducted a survey among 397 farmers attending a regional farm show in Raleigh, North Carolina to assess their attitudes and personal behaviors regarding sun protection and risk for skin cancer.[21] The 2012 study found that while the majority of farmers recognized the importance of sun safety and the risks of skin cancer, their actual use of proper protection methods was low. The most commonly reported form of sun protection among farmers was wearing a baseball cap, which does not protect the back of the neck or ears from the sun. The study's findings suggest that more preventive efforts are needed to support the use of sun safety measures among farmers. The authors of the study have proposed that additional promising interventions such as the "Operation Hat Check," that encourages farmers to exchange their baseball hats for wide-brimmed hats, are needed in North Carolina.[20]

4. Melanoma skin cancer

Melanoma is a type of skin cancer that originates in the cells that produce melanin pigment. The overall prevalence of diagnosed melanoma has increased in the United States over previous decades, though the rate of increase in prevalence has slowed considerably since the 1970s.[21] While there are several important individual-level variables influencing melanoma risk, the strongest environmental risk factor is exposure to UV radiation, which is estimated to cause 65% to 90% of all melanomas.[22]

The annual incidence rate and death rates of melanoma in North Carolina between 2005 and 2009 were slightly higher than the national rates (Table 1). As shown in Figure 3, the overall incidence of melanoma has been generally increasing in North Carolina since 2000. Incidence rates were consistently higher among males, though there was a slight decrease between 2004 and 2006. It is important to note that the increasing trend in melanoma incidence rates over the past decade is partly attributable to an increase in reporting of melanoma cases by dermatologists.[23]

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[20] Kearney GD et al 2013. Assessment of Sun Safety Behavior among Farmers Attending a Regional Farm Show in North Carolina. Journal of Agromedicine. (18)1, 65-73.

[21] Tucker MA. 2009. Melanoma Epidemiology. Hematology Oncology Clinics of North America (23): 383-395.

[22] Armstrong BK, Kricker A. How much melanoma is caused by sun exposure? *Melanoma Research*1993;3(6):395–401.

[23] North Carolina Central Cancer Registry. A Fact Sheet from the North Carolina Central Cancer Registry, State Center for Health Statistics. Melanoma. June 2011. Accessed http://www.schs.state.nc.us/schs/pdf/Melanoma_Cancer_2011.pdf 15 Mar 2013.

Figure 4 reflects the well-documented trend of higher melanoma incidence rates among whites, particularly white males. Melanoma incidence in North Carolina is highest in the piedmont regions and western tip of the state, as well as in several coastal counties (Figure 5). Rural counties with small populations are excluded from this map for confidentiality reasons, so it is unknown whether additional coastal and mountain counties also have high incidence rates.

Table 1: NC and U.S. melanoma incidence and mortality rates, 2005-2009[24]

	Annual incidence rate/100,000	Confidence Interval	Average annual incidence (n)	Annual death rate/100,000	Confidence Interval	Average deaths per year (n)
NC	21.5	21.1 – 21.9	2001	3.1	2.9 – 3.3	287
U.S.	19.2	19.2 – 19.3	~	2.7	2.7 – 2.8	8,614

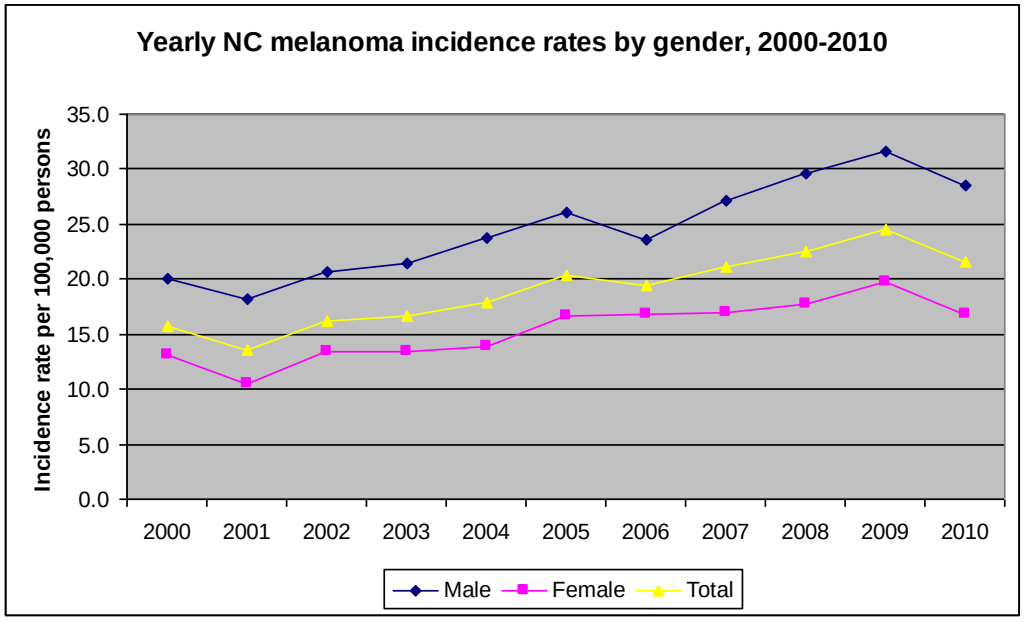

Figure 3: NC melanoma skin cancer incidence rates by gender, 2000-2010[25]

[24] National Cancer Institute, State Cancer Profiles. Created by statecancerprofiles.cancer.gov on 3/15/2013 at 11:21 am. Accessed http://statecancerprofiles.cancer.gov/cgi-bin/quickprofiles/profile.pl?37&053 14 Mar 2013. Incidence rates (cases per 100,000 population per year) are age-adjusted to the 2000 US standard population. Annual incidence rate/100,000 is over rate period. Population counts for denominators are based on Census populations as modified by NCI.

[25] Produced by the NC Central Cancer Registry, 03/2013. Numbers are subject to change as files are updated. Data are age-adjusted to the U.S. 2000 Census.

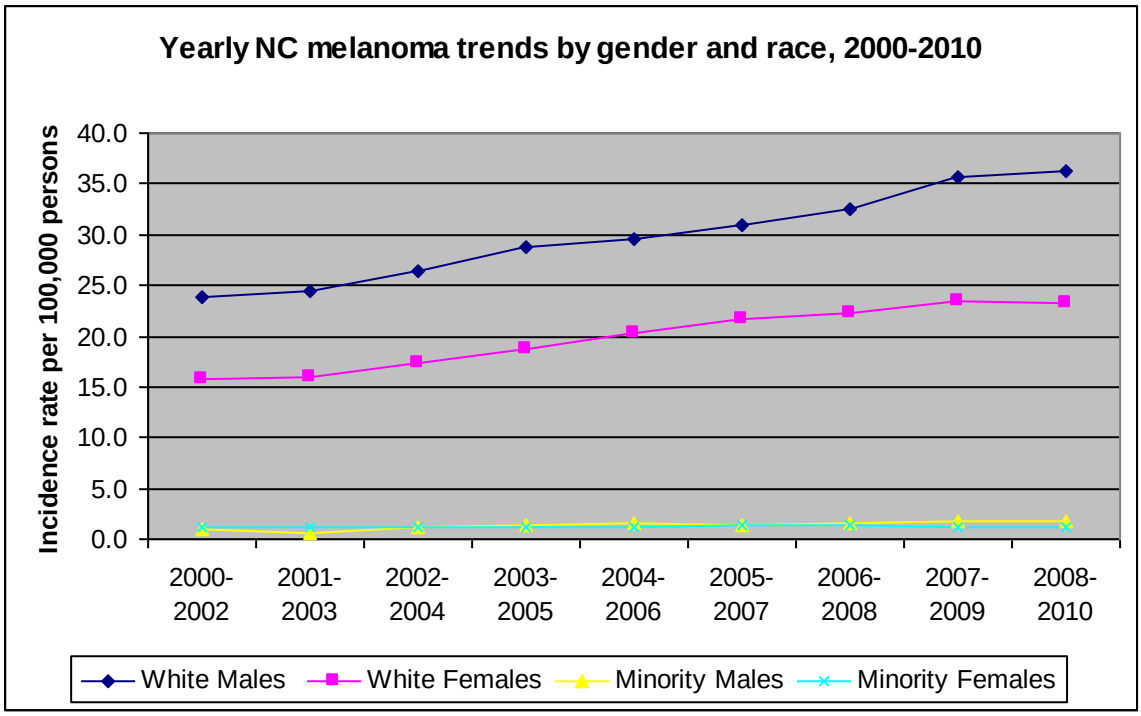

Figure 4: NC gender- and race-stratified melanoma incidence rates, 2000-2010[26]

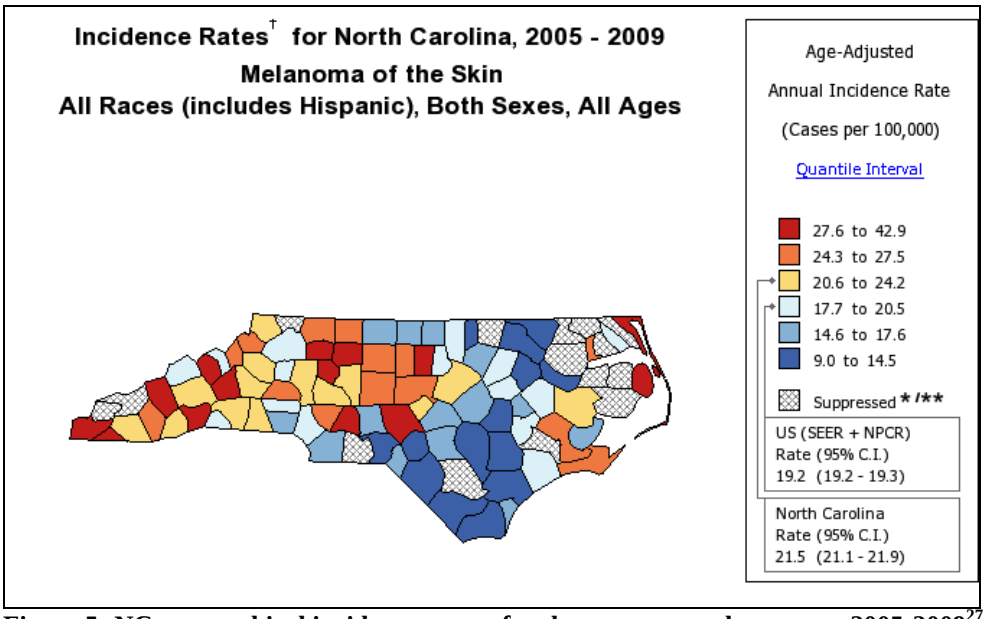

Figure 5: NC geographical incidence rates of melanoma cancer by county, 2005-2009[27]

[26] Produced by the NC Central Cancer Registry, 03/2013. Numbers are subject to change as files are updated. Age-adjusted to the U.S. 2000 Census.

5. Colorectal cancer

Colorectal cancer refers to all cancers that originate in the colon or rectum. In the United States, colorectal cancer was the fourth most common, and the fourth most deadly, form of all cancers among men and women in 2009.[28] Because of the protective effect of increased vitamin D circulation caused by increased sun exposure, colorectal cancer is a unique example of a health condition that may improve in response to climate change.[29,30]

Comparing the five-year intervals of 2001-2005 and 2006-2010, the colorectal cancer incidence rate in North Carolina has dropped from 49.6 to 43.3 per 100,000 persons (Table 2). Males in North Carolina have continued to experience higher rates of colorectal cancer than females since 2000 (Figure 6). Between 2001 and 2005, the three highest incidence rates of colorectal cancer were found in Bertie County (69.9 per 100,000 persons), Hertford County (68.6), and Perquimans County (68.3).[31] Between 2006 and 2010, however, the top three highest incidence rates for colorectal cancer were in Washington County (62.6 per 100,000 persons), Warren County (61.6) and Lenoir County (60.9).[32]

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[27] National Cancer Institute. Produced by statecancerprofiles.cancer.gov on 3/13/2013 at 10:02 pm. Age-adjusted to the 2000 standard U.S. Census population; grey-shaded counties labeled "suppressed" are those where counts fewer than 16 require suppression to ensure confidentiality of subjects.

[28] CDC. Cancer: Colorectal (colon) cancer. Accessed http://apps.nccd.cdc.gov/uscs/toptencancers.aspx 15 Mar 2013.

[29] Garland, C. F., Gorham, E. D., Mohr, S. B., & Garland, F. C. (2009). Vitamin D for cancer prevention: global perspective. *Annals of epidemiology*, *19*(7), 468-483.

[30] Portier CJ et al 2010. A Human Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272. Accessed www.niehs.nih.gov/climatereport 12 Feb 2013.

[31] Produced by the NC Central Cancer Registry, 3/2008. Numbers are subject to change as files are updated. Rates based on counts of less than 16 are unstable. Accessed http://www.schs.state.nc.us/schs/CCR/incidence/2005/5yearRates.pdf 14 Mar 2013.

[32] Produced by the NC Central Cancer Registry, 1/2013. Rates are calculated using the bridged-race population estimates obtained from the National Center for Health Statistics available online at www.cdc.gov/nchs/nvss/bridged_race/data_documentation.htm#vintage2011. Rates based on counts less than 16 are unstable. Cases may not sum to totals due to unknown or other values. Accessed http://www.schs.state.nc.us/schs/CCR/incidence/2010/5yearRates.pdf 13 Mar 2013.

Table 2: NC colorectal cancer cases and incidence rates, 2001-2005 and 2006-2010[33]

2001-2005		2006-2010	
Number of cases	**Rate per 100,000 persons**	**Number of cases**	**Rate per 100,000 persons**
20,822	49.6	20,968	43.3

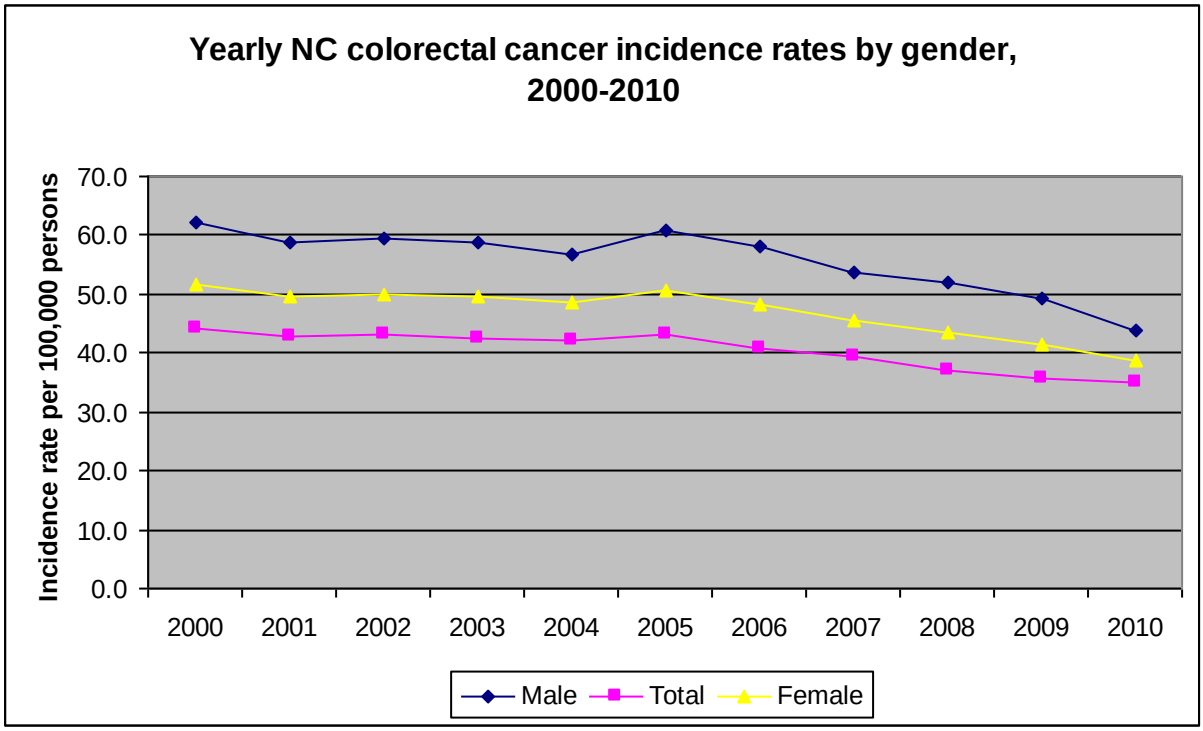

Figure 6: NC colorectal cancer incidence rates by gender, 2000-2010[34]

IV. Conclusion

To date, researchers are continuing to investigate the effects of climate change on cancer risk among humans. As ambient temperatures rise as a result of climate change, North Carolina could potentially experience an increase in high ultraviolet days and hot temperature days, as well as increased rates of melanoma skin cancers. On the other hand, future trends may reflect lower colorectal cancer rates associated with increased ultraviolet radiation exposure.

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[33] Produced by the NC Central Cancer Registry, 03/2013. Numbers are subject to change as files are updated. Age-adjusted to the U.S. 2000 Census. Accessed http://www.schs.state.nc.us/schs/CCR/incidence/2010/5yearRates.pdf 14 Mar 2013.

[34] Produced by the NC Central Cancer Registry, 03/2013. Numbers are subject to change as files are updated. Age-adjusted to the U.S. 2000 Census. Rates are calculated using the bridged-race population estimates obtained from the National Center for Health Statistics available online at www.cdc.gov/nchs/nvss/bridged_race/data_documentation.htm#vintage2011.

As researchers continue to explore the relationships between the effects of climate change and cancer, it is important to recognize that a myriad of factors remain unknown. For example, some researchers predict that increased precipitation and flooding could possibly damage storage facilities containing toxic chemicals, which in turn could increase the risk for cancer. However, this causal pathway has yet to be extensively studied. Most importantly, there is no definitive evidence to conclude that increases in cancer morbidity are directly or solely attributable to climate change.[35] Nonetheless, monitoring environmental and health indicators related to climate change and cancers in North Carolina today will lead to a better understanding of this complex issue.

[35] Portier CJ et al 2010. A Human Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272. Accessed www.niehs.nih.gov/climatereport 12 Feb 2013.