Health Effects of Precipitation Abundance and Deficits in Florida

Florida HEALTH

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Table of Contents

List of Figures

List of Tables

Executive Summary

Despite a generally wet climate, Florida is vulnerable to drought. While there are no discernable changes in long-term trends, the multidecadal variability in the northern part of the state is similar to the rest of the southeastern U.S., and in southern Florida, patterns are similar to the Caribbean region. Future scenarios indicate possible changes in the geographic vulnerability to drought statewide by the year 2100; areas that may experience high or extreme drought risk include central and southern Florida and the Panhandle. While there may be geographic variation in severity, drought can affect human and natural systems statewide. Local and state planning efforts should consider this hazard, so that communities can mitigate the risk and/or adapt to future conditions.

There are important public health implications from drought conditions, including the potential increase in respiratory illness due to dry air and airborne particles, a need for water conservation leading to poor hygiene and food safety concerns, concentration of sediments in dwindling water supplies providing a nutrient rich environment for pathogens, and increased contact between humans, animals, and vectors near remaining water sources. To examine the relationship between drought and foodborne and waterborne diseases, rates of *Campylobacter, Cryptosporidium, Giardia, Salmonella*, and *Vibrio* infections were calculated using notifiable disease surveillance records from 2005-2012. To examine the relationships between drought and respiratory diseases, rates of allergic rhinitis, asthma, and all respiratory disease-related (excluding asthma) emergency department (ED) visits were calculated using Agency for Health Care Administration (AHCA) data from 2005-2012. Monthly climate data were obtained from the National Climatic Data Center (NCDC) from 2005-2012. Data included monthly average temperatures (degrees Fahrenheit) and several drought indices. One- and three-month Standardized Precipitation Indices (SPI) were used to assess short-term and medium-term drought, respectively.

After analyzing this data, drought has inconsistent relationships with the foodborne and waterborne diseases of interest in Florida. In general, the extreme categories of drought are rare, and seem to be protective for some of these diseases. More moderate drought conditions are associated with increased cases of cryptosporidiosis and giardiasis and decreased cases of salmonellosis. Drought is significantly associated with the rate of ED visits for all respiratory diseases, and specifically for asthma and allergic rhinitis. This relationship varied by disease. In general, the most extreme drought conditions were protective against respiratory illness, while more moderate drought tended to be associated with an increase in ED visits for these diseases, especially with shorter-term drought measures.

Historic Patterns

The wet climate of Florida is punctuated by extended dry periods in which very warm temperatures rapidly dry out the soil. Many of the droughts across Florida are relatively short in duration (e.g., several months), owing to the close proximity of large bodies of water and the regular occurrence of tropical disturbances, such as tropical waves, tropical storms, and hurricanes. Across the southern portions of the state, extended dry periods are common during the winter and early spring months of the year. Because of its proximity to the continental portions of the U.S., the extreme northern part of the state periodically experiences more persistent droughts (e.g., durations of six months to two years). These hydrological droughts lower the water table and can strongly impact water availability. While uncommon in South Florida, these more persistent droughts are sometimes observed.

Much inter-annual and inter-decadal variability is found in the frequencies of drought across Florida (Figure 1). Though droughts were especially prevalent in the early twentieth century, no long-term trend is found in frequency of droughts for the state as a whole. In southern sections of the state, however, the frequencies of drought have increased slightly over the 100-year period, while in northern Florida, drought frequencies have decreased slightly.

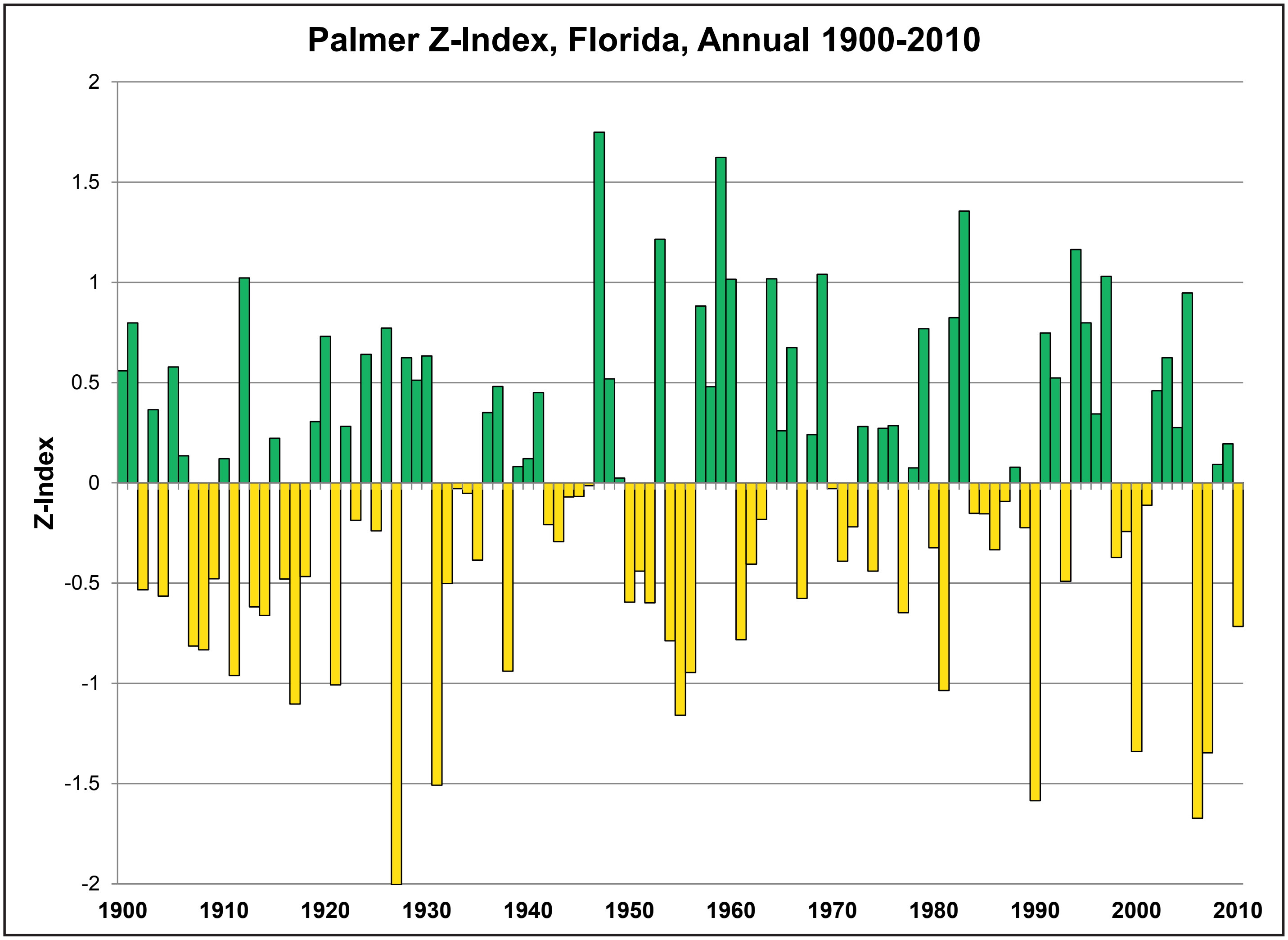

Figure 1. The annual Palmer-Z index: Florida 1900-2010. Negative values are associated with dryness and drought (Source: National Climatic Data Center).

The patterns of drought across northern Florida are similar to those observed across the broader southeastern region of the U.S. Climate reconstructions using tree rings in the Southeast reveal significant multidecadal variability in precipitation and soil moisture over the past millennium with no discernible long-term trend (Doublin & Grundstein, 2008; Ortegren, Knapp, Maxwell, Tyminski, & Soue, 2011; Seager, Tzanova, & Nakamura, 2009; Stahle & Cleaveland, 1992). In particular, the reconstructions suggest that the severity and duration of several prominent twentieth and early twenty-first century droughts are not unusual in the longer-term context, and that decade-long droughts have occurred periodically in the Southeast during the past 1,000 years (Konrad & Fuhrmann, 2013).

The patterns of drought across southern Florida correlate with those observed across the larger Caribbean region. Both instrumental and proxy records indicate significant multidecadal variability in Caribbean precipitation dating back over 800 years that appears to be linked to variations in the North Atlantic Oscillation (NAO) (Malmgren, Winter, & Chen, 1998) and the Atlantic Multidecadal Oscillation (AMO) (Winter, 2011). In addition, Caribbean precipitation is affected by the strength and positioning of the Intertropical Convergence Zone (Kilbourne et al., 2010), a prominent feature in the global circulation that controls where the heaviest precipitation occurs.

Geographic Vulnerability

Although other indices are available, the SPI is recommended for studying environmental health outcomes in the eastern U.S. because the index can project emerging droughts sooner than other indices (English et al., 2009). The SPI is based on the probability of precipitation for a given time and a given place. This index is calculated "by comparing the total cumulative precipitation for a particular station or region over a specific time interval with the average cumulative precipitation for that same time interval over the entire length of the record" (National Oceanic and Atmospheric Administration [NOAA], 2014). SPI is calculated on a scale of -3 to +3, where negative values indicate drier conditions, and positive values indicate wetter conditions (Table 1).

To describe vulnerability to drought in Florida, the average three-month SPI was calculated for summer (June, July, and August) and year-round for the year 2100. Potential drought hazard for summer is shown to highlight areas where extreme seasonal drought may occur because annual risk is low statewide due to significant precipitation (approximately 58 inches annually). SPI values were plotted using precipitation data from the Intergovernmental Panel on Climate Change's Fourth Assessment Report (AR4) (Maurer, Brekke, Pruitt, & Duffy, 2007). The three-month SPI was calculated for each month by comparing the past three months of precipitation with the baseline average of precipitation of those three months. The three-month SPI values were then averaged to give a mean value for looking at short-term and medium-term drought conditions. Results represent the middle range of projections for three AR4 scenarios: the B1 scenario (the best outcome), the A1B scenario (the middle of the road projection), and the A1F1 scenario (shows a world highly dependent on fossil fuels).

SPI values are categorized as follows:	
-2.00 and less	Extremely dry
-1.50 to -1.99	Very dry
-1.00 to -1.49	Moderately dry
0.99 to -0.99	Near normal
1.00 to 1.49	Moderately wet
1.50 to 1.99	Very wet
2.00 and greater	Extremely wet

Table 1. Classification of Standardized Precipitation Index values.

The B1 scenario shows South Florida most at risk of drought in 2100, with areas in both medium- and high-risk categories (Figure 2A). All census tracts in Broward, Collier, Hendry, Miami-Dade, Monroe, and Palm Beach counties are in the high-risk category, totaling almost 7 million people at high risk of drought and 1.5 million at medium risk. The A1B scenario places most of the northern part of the state in the low drought risk category, with higher risks occurring in the central and southern parts of Florida (Figure 2B). The counties most at risk are Broward, Miami-Dade, and Palm Beach counties, with tracts in the extreme-risk category. This projection places over 4 million people at extreme risk to drought in 2100, with another 9.8 million in the medium- and high-risk categories. The A1FI scenario shows the most intense drought projections, with all of South Florida falling into the extreme drought risk category (Figure 2C), and parts of the western Panhandle reaching the high-risk category. This projection places 7.7 million people at extreme risk to drought in 2100, with another 7.6 million people in the medium- and high-risk categories.

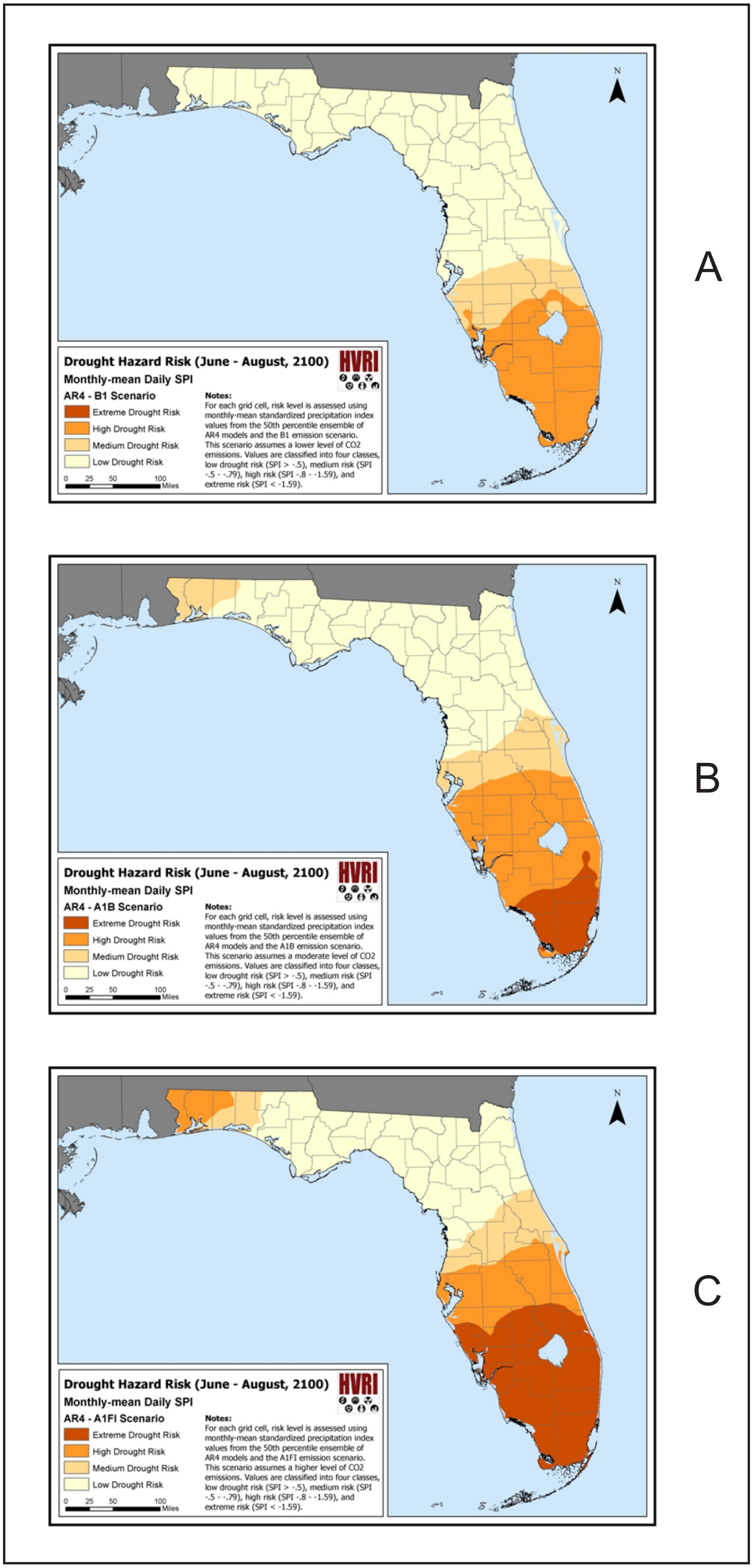

Figure 2. Monthly-mean daily SPI in Florida: June-August, 2100. A) B1 scenario B) A1B scenario C) A1F1 scenario (Source: Hazards and Vulnerability Research Institute).

Health Implications

The human health impacts of drought have been scientifically studied since the early twentieth century. Although the focus of early work is nutritional deficiencies caused by famine during World War I and the Dust Bowl, Ravenel comments on increased cases of gastrointestinal disease, vectorborne disease, and mental health outcomes (1931). In 2010, the CDC, U.S. Environmental Protection Agency, and NOAA released a comprehensive guide for public health professionals which focuses on compromised potable water and food, diminished living conditions (including air quality and sanitation), and increased disease incidence. Specific impacts are place-specific and dependent on the severity and duration of the event.

Waterborne disease, foodborne disease, and coastal ecosystems are closely interrelated, and disease outbreaks are often associated with excess precipitation that overwhelms the capacity of water treatment facilities (Rose et al., 2001). However, according to English et al. (2009) citing the Georgia Water Advisory Group (2007), "drought indicators should be monitored by public health officials because drought is associated with degraded water quality and quantity, waterborne disease, and food safety, among other concerns." Because surface water, and potentially ground water, is scarcer during droughts, harmful agents in water (either biological or chemical contaminants) become more concentrated. In addition, hygiene may be compromised due to a reduction in available water (Rose et al., 2001).

Drought conditions have also been linked to increased incidences of respiratory disease (Smith, Aragao, Sabel, & Nakaya, 2014). Exposure to airborne particulate matter (i.e., dust) can overwhelm the respiratory system (Griffin, Kellogg, & Shinn, 2001). In addition to the basic mechanism of inhaled particles irritating the nose and lungs leading to allergies and other respiratory diseases, dust can also transport bacteria, fungi, viruses, pesticides, and other harmful agents that can cause human disease (Griffin et al., 2001). In addition to increases in potentially harmful particulate matter originating locally during a drought, Floridians may be exposed to dust originating from elsewhere in the U.S. during the spring (Prospero, 1999), and from dust transported across the Atlantic Ocean from Africa during the summer and early fall (Griffin et al., 2001).

Broad adaptation strategies that could be employed to protect public health before and during droughts include sustained water management programs, actions to protect drinking water supplies, monitoring of particulate matter, and ongoing disease surveillance, especially for underreported gastrointestinal illness.

Methods

From 2005 to 2012, climate regions throughout Florida were classified as near normal 66.4% of the time, drought conditions 18.2% of the time, and wet conditions 15.5% of the time using one-month SPI. A similar distribution was seen using three-month SPI (near normal [65.0%], drought [19.4%], and wet [15.6%]). Though not statistically significant, there were differences in drought by climate region throughout Florida (Figure 3). Based on one-month SPI, North Central Florida (25.0%) and the Keys (24.0%) experienced the greatest proportion of months in drought conditions while the lower east coast (13.5%) experienced the least. According to three-month SPI, North and North Central Florida (24.0% each) and the Keys (21.9%) had the greatest proportion of drought months, while the Everglades and the southwest coast (13.5%) experienced the least.

A variety of health data sources are readily available in Florida to study the effects of weather hazards and variability on human health outcomes. Using existing data sources is beneficial for several reasons. They provide immediate access to data to understand historical trends and associations between weather and public health, and they collect information statewide on a variety of health outcomes and diseases. However, using these data sources is not without limitations. These data sources were mostly created for surveillance or quality assurance purposes and were not intended for research in general or to specifically study the effects of weather hazards on health. Information on data sources can be found in Appendix 1.

Most of the diseases considered in relation to drought for this report are acute in nature, as we are more concerned with the short-term effects of drought. While the respiratory diseases of interest are considered chronic, with individuals suffering from the effects of these diseases for many years or throughout their lifetimes, we are interested in the acute, more immediate triggers of asthma, allergy, or other respiratory illness episodes. Therefore, we will consider both the one-month and three-month measures of drought.

We examined associations between monthly drought conditions and rates of disease or rates of ED visits for specific health conditions among Florida residents from 2005 to 2012. Because the effects of drought may be exacerbated by extreme temperatures in the summer months, we also conducted sensitivity analyses to determine if there were any differences in these relationships in Florida from May through October only. All associations were assessed using Poisson regression models. Rate ratios (RR) and 95% confidence intervals are reported. A RR is the ratio of the rate in an exposed group compared to or divided by the rate in an unexposed group. A RR equal to 1.50 can be understood as the rate in the exposed group is 50% greater than the rate in the unexposed group. In this study, a RR describes the rate of disease or rate of ED visits in drought months (exposed) compared to normal months (non-exposed). For each RR estimate provided in this report, there is a 95% confidence interval around this estimate. This interval can be interpreted as the range in which the true estimate would fall 95% of the time.

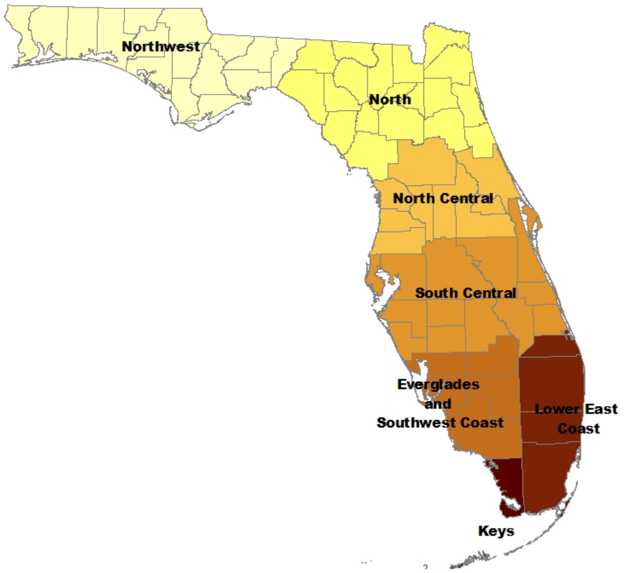

Figure 3. National Climatic Data Center Regions (Source: National Climatic Data Center).

Foodborne and Waterborne Disease

The foodborne and waterborne diseases chosen as health indicators for this study are notifiable diseases in Florida (Table 2). *Campylobacter* and *Salmonella* are bacterial diseases more commonly associated with foodborne transmission. *Giardia* and *Cryptosporidium*, protozoan diseases, and *Vibrio,* a bacterial disease, are more commonly associated with waterborne transmission and contamination of water sources. For some of these diseases, there are other modes of transmission besides foodborne or waterborne, such as environmental exposure and zoonotic or person-to-person transmission. Affected individuals, known as cases, often have mild or asymptomatic infections, and many cases do not seek treatment and are not reported.

Burden of Disease

Foodborne and Waterborne Disease	
Measures	1. Number of notifiable disease reports for health outcome
	2. Crude rate of notifiable disease reports for health outcome per 100,000 population
Numerator by Health Outcome of Interest	*General:* Notifiable disease reports for Florida residents during the time period of interest with the associated diagnosis of interest, all case classifications
	1. *Campylobacteriosis:* enteric disease caused by bacteria from the genus *Campylobacter*
	Confirmed: *Campylobacter* isolated using culture techniques
	Suspect: *Campylobacter* isolated using non-culture techniques
	Probable: has clinical symptoms and is linked to a confirmed case
	2. *Cryptosporidiosis:* protozoan diarrheal disease caused by *Cryptosporidium parvum*
	Confirmed: evidence of *Cryptosporidium* organisms or DNA
	Probable: has clinical symptoms and is linked to a confirmed case or *Cryptosporidium* antigen present
	3. *Giardiasis:* protozoan diarrheal disease caused by *Giardia lamblia*
	Confirmed: evidence of *G. lamblia* cysts, trophozoites, antigen, or DNA
	Probable: has clinical symptoms and is linked to a confirmed case
	4. *Salmonella:* enteric disease caused by bacteria from the genus *Salmonella*
	Confirmed: *Salmonella* isolated using culture techniques
	Suspect: *Salmonella* isolated using non-culture techniques
	Probable: has clinical symptoms and is linked to a confirmed case
	5. Vibriosis: enteric disease caused by bacteria from the genus *Vibrio*
	Confirmed: *Vibrio* isolated using culture techniques
	Probable: has clinical symptoms and is linked to a confirmed case
	Data Source: Florida Department of Health, Notifiable Disease Surveillance System (Merlin)
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Geography	*Scope:* State and National Oceanic and Atmospheric Administration regions
	Scale: Region experiencing drought
Time Scale	*Period:* 2005 to 2012
	Scale: Annual, during drought period

Table 2. Foodborne and waterborne disease indicator.

Campylobacter: Campylobacteriosis is an enteric disease caused by bacteria from the genus *Campylobacter*. The illness is characterized by diarrhea, often with bloody stools, malaise, fever, abdominal pain, nausea, and vomiting. This is a zoonotic infection most commonly found in cattle and poultry, and usual mode of transmission is ingestion of the bacteria from undercooked meat, raw milk, and other contaminated sources (*Control of Communicable Diseases Manual* [*CCDM*], 2008; Florida Department of Health, 2011). It is estimated that 80% of all cases are foodborne. The estimated number of annual U.S. cases is over 2.4

million, and the ratio for reported to unreported cases is 1:38 (Mead et al., 1999).

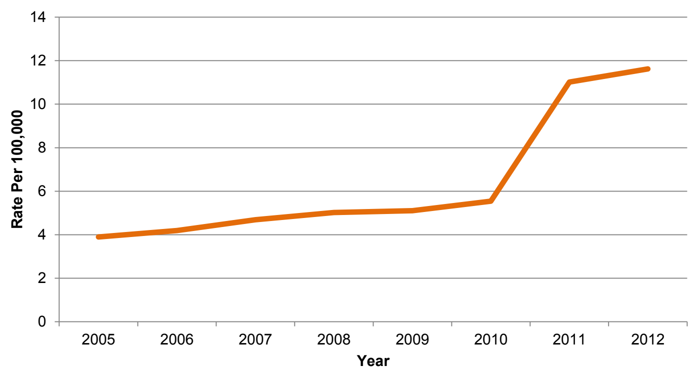

Figure 4. Rate of campylobacteriosis per 100,000 population, Florida, 2005-2012.

Since 2005, approximately 1,200 cases of campylobacteriosis were acquired in Florida and reported each year among Florida residents (average annual incidence rate: 6.4 per 100,000 population) (Figure 4). A change in case definition occurred in 2011 allowing for inclusion of enzyme immunoassay positive results to be considered as probable cases. This change in definition resulted in an increase in the average number of cases reported per year, from 880 to 2,150. The greatest number of cases are reported from May through September, with these months accounting for almost half of all cases annually. Campylobacteriosis is most commonly reported among infants and young children (ages 0 to 4 years: 21%), males (53%), and non-Hispanic white residents (55%). The highest rates of illness occur mainly in rural Gulf Coast counties from Taylor to Levy County.

Cryptosporidium: Cryptosporidiosis is a protozoan diarrheal disease caused by *Cryptosporidium parvum.* Diarrhea and abdominal cramps are the most common symptoms, and this illness is often associated with poor appetite and vomiting in children. Asymptomatic cases are common, which is a main source of fecal-oral infection of others. Waterborne transmission is common, but *C. parvum* can be passed via foodborne or zoonotic transmission. Humans and cattle are the most common carriers (*CCDM*, 2008). It is estimated that about 1 in 45 cases are reported, yielding an annual U.S. case count of 300,000, with 10% being related to foodborne transmission (Mead et al., 1999). Over a 36-year period in the U.S., *Cryptosporidium* was identified as the pathogen in 9% of parasitic waterborne disease outbreaks, causing 94% of all outbreak-related cases, due to one large outbreak in Wisconsin that yielded approximately 403,000 cases (Craun et al., 2010).

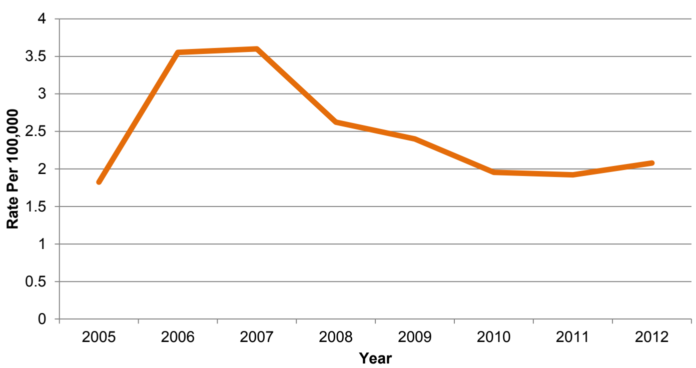

Figure 5. Rate of cryptosporidiosis per 100,000 population, Florida, 2005-2012.

There were 465 cases of cryptosporidiosis reported annually on average from 2005 through 2012 (average annual incidence rate: 2.5 per 100,000) among Florida residents (Figure 5). Most cases were reported from June through October (63%), among infants and children (ages 0 to 4 years: 19%), and non-Hispanic white residents (62%). The highest incidence rates are reported in Northeast and North Central Florida from Nassau down to St. Johns and over to the west coast in Levy County.

Giardia: Giardiasis is a gastrointestinal illness caused by the protozoan *Giardia lamblia* (aka *G. intestinalis* or *G. duodenalis*). Usual symptoms include diarrhea, fatigue, abdominal cramps, bloating, weight loss, and malabsorption. Humans are the main reservoir, but beavers and other wild animals are thought to be carriers. Contaminated drinking or recreational water and person-to-person transmission are common (*CCDM*, 2008). It is estimated that 2 million cases occur annually in the U.S., with only 5% of all cases being reported (1:20 ratio). Only about 10% of *Giardia* cases are associated with foodborne transmission (Mead et al., 1999). Waterborne transmission

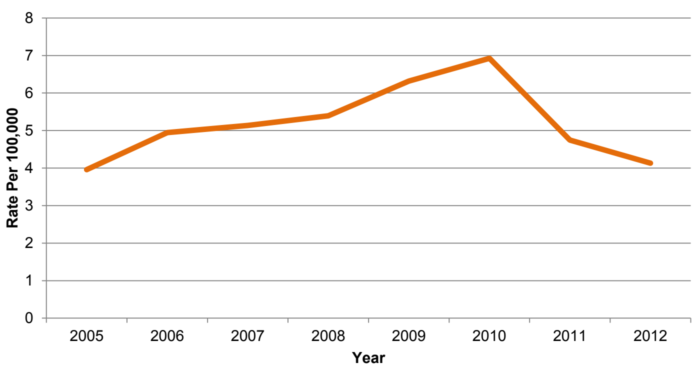

Figure 6. Rate of giardiasis per 100,000 population, Florida, 2005-2012.

is more common in the U.S., with 33% of all waterborne disease outbreaks with a known etiology being caused by parasitic diseases, and 86% of drinking water outbreaks of parasitic etiology being caused by *G. intestinalis* (Craun et al., 2010).

From 2005 to 2012, approximately 970 cases of giardiasis were reported each year (average annual incidence: 5.2 cases per 100,000) among Florida residents (Figure 6). In 2008, there was a change in reporting for giardiasis. Asymptomatic cases were included in the case definition, whereas only symptomatic cases had been included previously. Another change in 2011 reverted the definition to its original format (symptomatic cases). During the years including only symptomatic cases, the average number of cases reported annually was 850 (rate: 4.6 per 100,000), compared to 1,156 (rate: 6.2 per 100,000) in years that included asymptomatic cases. The majority of cases were reported from May through October (57%), among infants and children (ages 0 to 4 years: 24%), men (56%), and non-Hispanic white residents (53%). The highest rates of illness occur in North Central Florida from Gulf to Nassau County.

Salmonella: Salmonellosis is an enteric disease caused by bacteria from the genus *Salmonella*. This illness is characterized by sudden onset of acute symptoms such as headache, abdominal pain, diarrhea, nausea, fever, and sometimes vomiting. Dehydration is often a problem for the very young and very old (*CCDM*, 2008; Florida Department of Health, 2011). Carriers of *Salmonella* spp. include domestic and wild animals. Usual mode of transmission is ingestion of bacteria, either through consumption of contaminated, undercooked, or improperly handled food, or from environmental exposure and improper hand-washing techniques (*CCDM*, 2008). It is estimated that 95% of all cases of salmonellosis are foodborne; the estimated number of annual U.S. cases is approximately 1.5 million, and the ratio for reported to unreported cases is 1:38 (Mead et al., 1999).

Salmonellosis accounts for the greatest number of foodborne illnesses reported in Florida. On average, 5,438 cases of locally-acquired salmonellosis are reported each year among Florida residents (average annual incidence rate: 29.2 cases per 100,000), with 70% of cases reported from June through November (Figure 7). There has been a marked increase in incidence of salmonellosis between 2005 (rate: 28.5 per 100,000) and 2012 (rate: 32.5 per 100,000), with a 21% increase in the total number of cases reported annually. No known changes in reporting or testing have occurred during this period. This may be a true increase in incidence or may be due to an increased awareness of salmonellosis by Florida physicians or residents due to widely publicized national outbreaks. Areas with the highest rates of salmonellosis were in Northeast Florida (e.g., Nassau, Duval, and St. Johns counties) and the Panhandle (Okaloosa to Bay County).

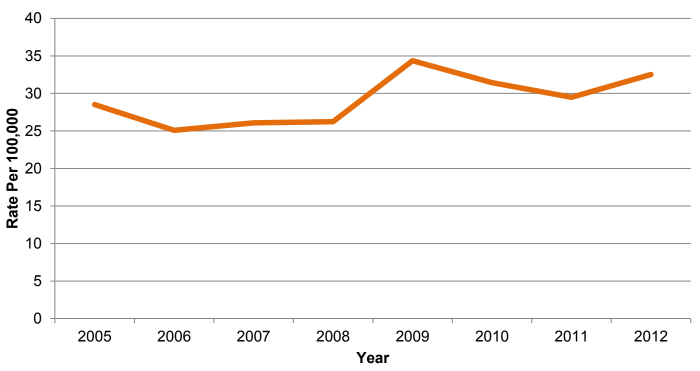

Figure 7. Rate of salmonellosis per 100,000 population, Florida, 2005-2012.

Vibrio: Vibriosis is caused by bacteria from the genus *Vibrio*, which includes species that cause very different types of illness. These range from the more serious illnesses caused by *V. cholerae* (cholera) and *V. vulnificus* to the milder *V. alginolyticus* and *V. parahaemolyticus*. *Vibrio* spp. are found in warm coastal waters worldwide and are often associated with contaminated water ingestion, raw oyster consumption, and wound infections. Symptoms can range from mild gastroenteritis (diarrhea, dehydration, nausea, vomiting) to primary septicemia. People with chronic and specific underlying conditions have a greater risk of septicemia. Vibriosis has the highest case fatality rate of any enteric disease (*CCDM*, 2008). Approximately 8,000 cases are estimated to occur each year in the U.S. Underreporting varies by type of vibriosis, with the more serious forms caused by *V. cholerae* and *V. vulnificus* having a 1:2 underreporting ratio while less serious species having approximately a 1:20 ratio (Mead et al., 1999). Approximately 100 cases are reported annually in Florida (Florida Department of Health, 2011).

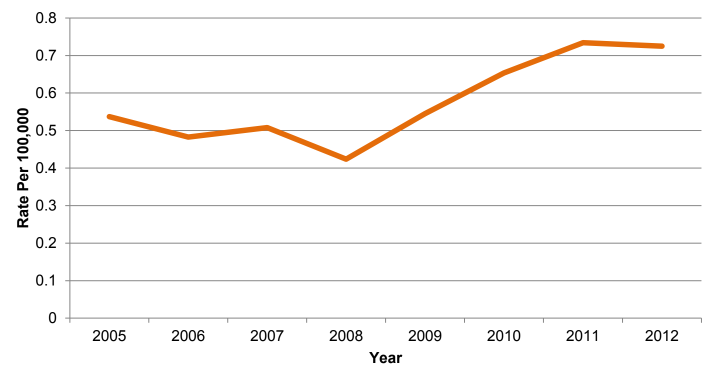

Figure 8. Rate of vibriosis per 100,000 population, Florida, 2005-2012.

Between 2005 and 2012, a total of 859 cases of vibriosis were reported among Florida residents, yielding an average of 107 cases per year (average annual incidence rate: 0.58 per 100,000) (Figure 8). As with most foodborne and waterborne illnesses, vibriosis has a distinct seasonal pattern, with 81% of cases occurring between April and October. There has been a marked increase in incidence of vibriosis between 2008 (rate: 0.42 per 100,000) and 2012 (rate: 0.72 per 100,000), with a 72% increase in the total number of cases reported annually. No known changes in reporting or testing have occurred during this period. This may be a true increase in incidence or may be due to an increased awareness of vibriosis by Florida physicians or residents because of educational campaigns and press releases from the Florida Department of Health (DOH).

The epidemiology of this disease is markedly different from other foodborne and waterborne diseases. Most cases of vibriosis are reported among individuals aged 35 to 74 years (58%) and male (74%), in contrast to the higher rates in infants and children and fairly even gender distribution of the other diseases considered in this report. Additionally, a greater number of cases are reported in coastal communities statewide. *Vibrio alginolyticus* (28%) was the most common *Vibrio* species reported during this time, followed by *V. parahaemolyticus* and *V. vulnificus* (25% each). Higher case rates are seen in the Panhandle of Florida.

Drought and Foodborne and Waterborne Disease

We examined associations between drought and specific foodborne and waterborne diseases, while controlling for year, season, climate region, and average monthly temperature (°F). During times of drought and water conservation, personal hygiene and food safety may suffer, along with the safety of the water supply. Especially in moderate drought conditions, the concentration of sediments and minerals in remaining water sources tends to increase as the water level decreases, providing a nutrient-rich environment for certain pathogens.

Drought has inconsistent relationships with the foodborne and waterborne diseases of interest in Florida. In general, the extreme categories of drought are rare, and seem to be protective for some of these diseases. More moderate drought conditions are associated with increased cases of cryptosporidiosis and giardiasis and decreased cases of salmonella.

***Campylobacter*:** When examining associations between rates of *Campylobacter* cases and drought, few statistically significant associations were identified. When looking at year-round associations for one-month SPI, only one category (moderately wet) was associated with a small decrease in rates of disease. Only one significant relationship was identified when using three-month SPI as the exposure of interest; very dry conditions were associated with an 11% increase in rates of campylobacteriosis (RR: 1.11; 95% CI: 1.01, 1.24). However, when limiting the data to summer months, the following categories showed a significant decrease in campylobacteriosis rates: extremely dry (RR: 0.74; 95% CI: 0.59, 0.92) and moderately wet (RR: 0.86; 95% CI: 0.78, 0.94) for one-month SPI (Figure 9), and no significant associations were identified using three-month SPI.

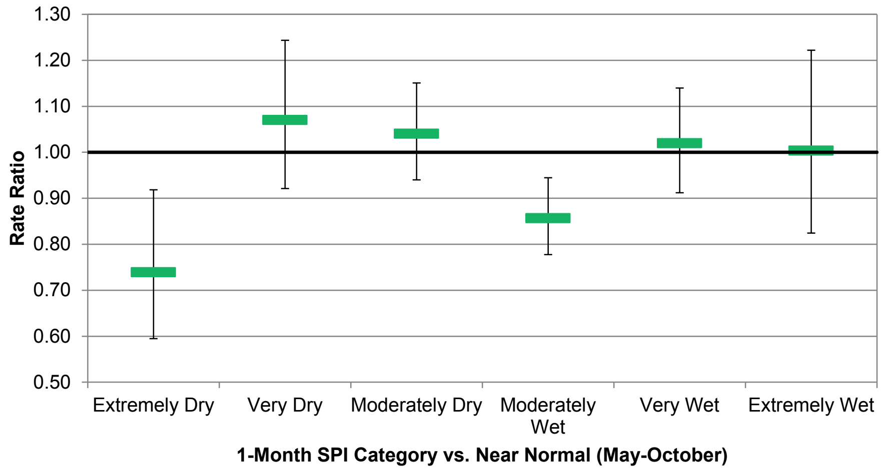

Figure 9. Associations between drought (one-month SPI) and campylobacteriosis, May-October, 2005-2012.

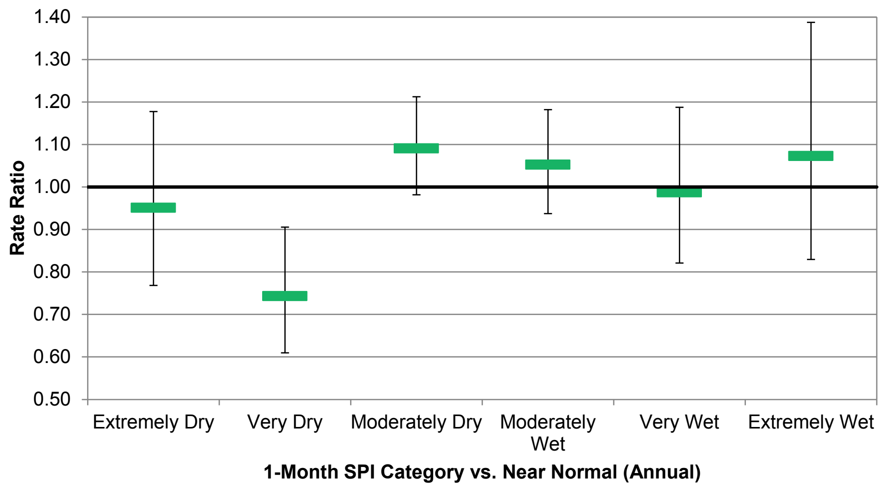

Figure 10. Associations between drought (one-month SPI) and cryptosporidiosis, annual, 2005-2012.

***Cryptosporidium*:** Conflicting relationships were identified when examining one- and three-month SPI with rates of cryptosporidiosis, both annually and in summer months. In the shorter-term, very dry conditions were associated with a 26% decline in rates (RR: 0.74; 95% CI: 0.61, 0.91) (Figure 10), though three-month drought conditions were associated with a marked increase in disease rates for extremely (RR: 2.12; 95% CI: 1.74, 2.59) and moderately (RR: 1.81; 95% CI: 1.58, 2.07) dry conditions. Furthermore, extremely wet conditions were associated with a 50% decrease in cryptosporidiosis rates. Similar trends were noted when limiting the analysis to summer months. Such discrepancies between the one- and three-month SPI measures may indicate that factors other than drought account for changes in cryptosporidiosis rates.

***Giardia*:** Few significant associations were identified for giardiasis. Extreme drought (RR: 1.15; 95% CI: 1.01, 1.30) and very wet (RR: 1.20; 95% CI: 1.08, 1.33) conditions were associated with an increase in cases for one-month SPI. No significant associations were seen with three-month SPI. When limiting to the summer months, only very wet conditions were associated with giardiasis using the shorter-term drought measure (RR: 1.18; 95% CI: 1.03, 1.35).

Salmonella: For salmonellosis, periods of extremely and very dry conditions were associated with a decrease in cases by 11-13% using one-month SPI (extremely dry RR: 0.87, 95% CI: 0.83, 0.93; very dry RR: 0.89, 95% CI: 0.85, 0.93). Rates were increased by 5% for moderately wet conditions (RR: 1.05; 95% CI: 1.02, 1.09) (Figure 11). For three-month SPI, very dry conditions were associated with a 7% increase in rates, while extremely wet conditions were associated with a 10% decrease in rates compared to near normal conditions. When limiting the analysis to the summer months, similar trends were seen with both drought measures. However, two categories of drought (very and moderately dry) were associated with increases in salmonellosis rates of 6-9%, and two categories of wet (moderate and extreme) were associated with reduced rates of 6-12%.

Vibrio: Due to the small number of cases of vibriosis reported annually, there were very low case rates available for inclusion in the analysis. Because of this, there was low power to detect significant associations between drought and vibriosis. In fact, no statistically significant relationships were identified, and no clear trend was observed.

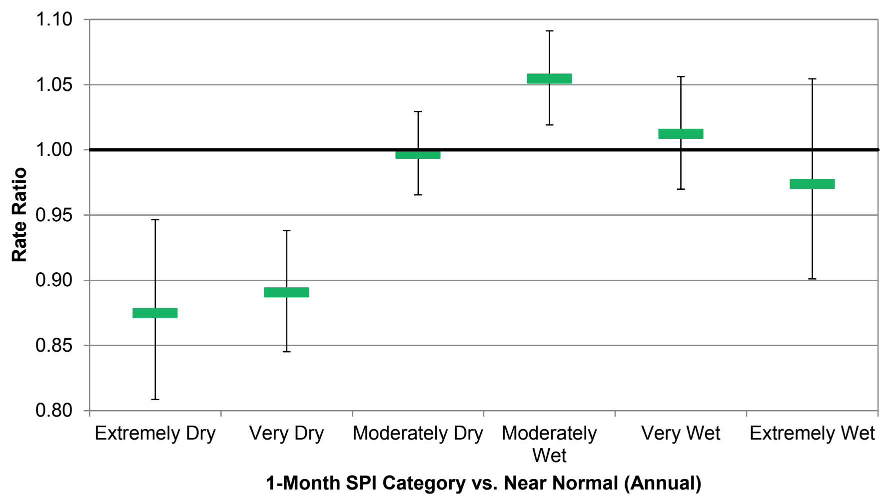

Figure 11. Associations between drought (one-month SPI) and salmonellosis, annual, 2005-2012.

Asthma, Respiratory Allergies, and Respiratory Disease

Respiratory diseases are public health priorities as prevalence, costs, and rates of ED visits and hospitalizations are increasing. In the U.S., asthma and allergic rhinitis each affect approximately 8% of adults and 10% of children (Centers for Disease Control and Prevention, 2014a, 2014b). Because chronic respiratory disease can often be controlled with proper education, clinical treatment, medication regimen, and environmental management, ED visits may be considered indicators of poorly controlled disease rather than of total prevalence or incidence. The change in rate of ED visits and hospitalizations, however, can be used as a proxy to track changes in the severity of these diseases over time (Florida Department of Health, 2013). For the purpose of this report, ED visits for the health outcomes of interest were based on either a primary or a secondary diagnosis (Table 3).

Burden of Disease

Allergic Rhinitis, Asthma, and Respiratory Disease	
Measures	1. Number of ED visits for health outcome
	2. Crude rate of ED visits for health outcome per 100,000 population
	3. Age-adjusted rate of ED visits for health outcome per 100,000 population
Numerator by Health Outcome of Interest	*General:* ED visits made by Florida residents during the time period of interest with the associated ICD-9-CM code of interest
	1. Allergic rhinitis: ICD-9-CM* code 477
	2. *Asthma:* ICD-9-CM code 493
	3. *Respiratory disease:* ICD-9-CM codes 460-519 (excluding asthma, 493)
	Data Source: Florida Agency for Health Care Administration
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Adjustment	*Method:* Direct age-adjustment using the 2000 U.S. Standard population
Geography	*Scope:* State and National Oceanic and Atmospheric Administration Regions
	Scale: Region experiencing drought
Time Scale	*Period:* 2005 to 2012
	Scale: Annual, during drought period

*ICD-9-CM, International Classification of Disease, 9th Revision, Clinical Modification

Table 3. Allergic rhinitis, asthma, and respiratory disease indicator.

Allergic Rhinitis: Allergic rhinitis, or hay fever, is a seasonal or perennial condition characterized by inflammation of the nasal passages, which leads to sneezing, itching, congestion, and/or runny nose. Of the respiratory conditions of interest, allergic rhinitis has seen the most pronounced increase in ED visits over time, from 7,232 visits in 2005 to 15,174 in 2012 (110% increase). On average, Floridians experience over 10,600 rhinitis-related ED visits per year for an average of 57.0 visits per 100,000 population (Figure 12). There are two main seasonal peaks in rhinitis visits: 35% of visits occur from March through May and a smaller peak (24%) from September through November. Similar to asthma, the majority of rhinitis-related ED visits occur in infants and children (ages 0 to 9 years: 27%), adults aged 25 to 44 years (25%), females (59%), and non-Hispanic white residents (45%). Rhinitis visits were most common in the Panhandle, North Central, and Central Florida, with the highest age-adjusted rates being in Union, Madison, and Franklin counties (>260.0 per 100,000).

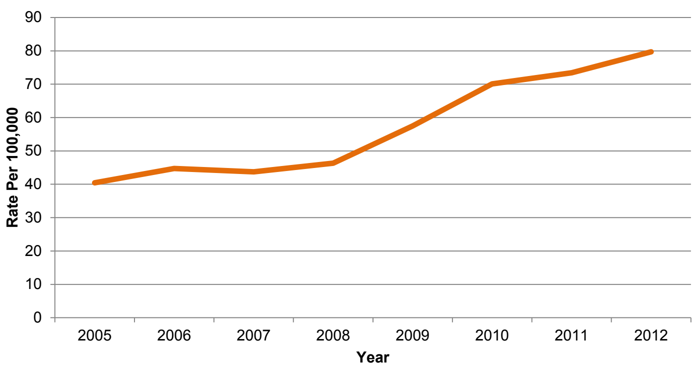

Figure 12. Rate of allergic rhinitis-related ED visits per 100,000 population, Florida, 2005-2012.

Asthma: Asthma is a chronic lung disease characterized by inflammation of the airways and recurring attacks of symptoms such as wheezing, coughing, and chest tightness. Annual ED visits for asthma have also increased over time (43%), from approximately 219,000 visits in 2005 to almost 313,000 visits in 2012. The average number of visits during this time was just over 257,000 with an average annual crude visit rate of 1,380 visits per 100,000 population (Figure 13). A similar seasonal trend was seen for asthma as with overall respiratory diseases with 46% of all visits occurring between March and November. Asthma-related ED visits are more common among children between the ages of 0 and 9 years (28%), adults between the ages of 25 and 54 years (37%), females (59%), and non-Hispanic white residents (46%). Higher average age-adjusted rates of ED visits occurred in the Panhandle and Central Florida, with the highest rates in Escambia (3,190 per 100,000), Polk (2,602 per 100,000), and Marion (2,511.4 per 100,000) counties.

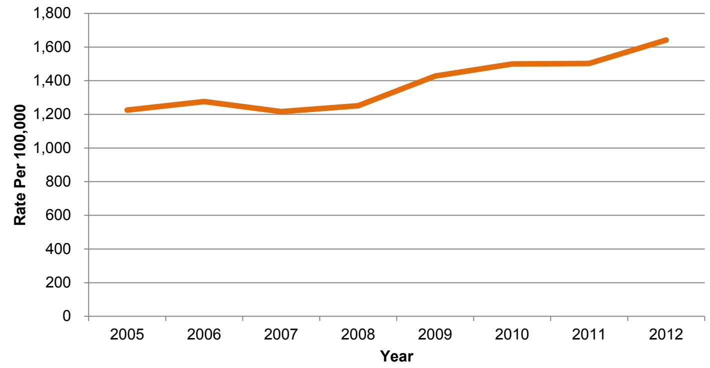

Figure 13. Rate of asthma-related ED visits per 100,000 population, Florida, 2005-2012.

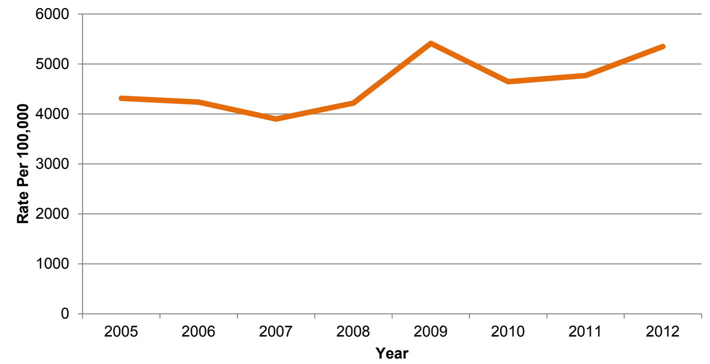

Figure 14. Rate of respiratory illness-related ED visits (no asthma) per 100,000 population, Florida, 2005-2012.

Respiratory Disease (Excluding Asthma): Respiratory disease excluding asthma includes, but is not limited to, acute respiratory infections (laryngitis, bronchitis), allergic rhinitis, pneumonia, influenza, chronic bronchitis, and chronic airway obstruction. Because asthma-related ED visits comprised between 21%-24% of annual respiratory-related ED visits in Florida from 2005-2012, asthma visits may distort the relationship that may exist between other respiratory diseases and environmental factors. From 2005 to 2012, 6.9 million ED visits occurred related to respiratory diseases (not including asthma), for an average of over 857,000 visits per year and a rate of 4,606 ED visits per 100,000 population (Figure 14). The number of visits has increased by 32% over this period, with just over one million visits occurring in 2009 and 2012. The majority of visits (49%) occurred between the months of November and March. Infants and children (ages 0 to 4 years) account for the largest majority of cases (28%). ED visits occur more frequently among females (56%) and non-Hispanic white residents (50%). Average age-adjusted rates of ED visits related to respiratory diseases were highest in the Panhandle, North Central, and Central Florida.

Drought and Respiratory Disease

We examined the relationship between drought and ED visits for allergic rhinitis, asthma, and all respiratory disease (excluding asthma), while controlling for the effects of year, season, climate region, and average monthly temperature (°F). Drought may cause an increase in respiratory illness due to the dry air and dust from lack of rainfall. Drought is significantly associated with the rate of ED visits for all respiratory diseases, and specifically for asthma and allergic rhinitis, in Florida. This relationship varies by disease. In general, the most extreme drought conditions were protective against respiratory illness, while more moderate drought tended to be associated with an increase in ED visits for these diseases, especially with one-month SPI.

Allergic Rhinitis: Allergic rhinitis exhibited a very different relationship with one- and three-month SPI than other respiratory diseases. When considering shorter-term drought (one-month SPI), a mild dose-response relationship appeared. Moderately and very dry conditions were associated with higher rates of rhinitis-related ED visits, an increase of 3-6% when compared to near normal conditions. This relationship was statistically significant for all but the most extremely dry months (very dry: RR: 1.06, 95% CI: 1.02, 1.07; moderately dry: RR: 1.05, 95% CI: 1.02, 1.07) (Figure 15). Wetter periods were associated with a decrease in rhinitis-related ED visits of 1-6%, though none were statistically significant. The relationship between rhinitis-related ED visits and three-month SPI was again associated with an 8-11% reduced rate of allergic rhinitis-related ED visits in the extremely and very dry months, while extremely wet months also showed a 7% decrease in ED visits. Moderately wet conditions were associated with a 13% increase in rates (RR: 1.13; 95% CI: 1.10, 1.16). The relationship between rhinitis-related ED visits and drought conditions were very different when focusing on summer months. There was no linear trend for one-month SPI in May through October, and extremely dry (RR: 0.93; 95% CI: 0.87, 0.99) and very wet conditions (RR: 0.93; 95% CI: 0.88, 0.97) were associated with a decrease in rates. For three-month SPI, moderately wet conditions remained a risk factor for higher ED rates, while very wet and dry conditions remained associated with reduced rates.

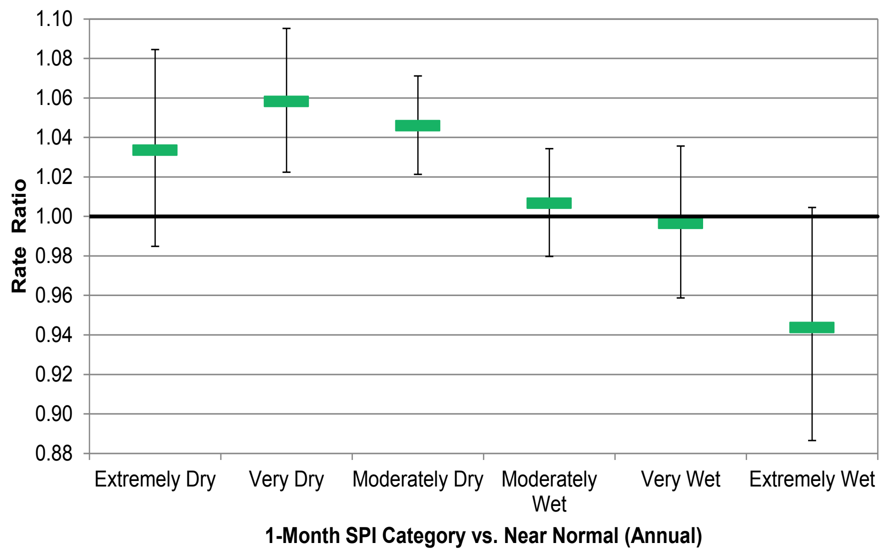

Figure 15. Associations between drought (one-month SPI) and allergic rhinitis, annual, 2005-2012.

Asthma: Drought conditions had a similar relationship to asthma as with other respiratory diseases. Extremely wet and dry periods were associated with a decreased rate of asthma-related ED visits. Extreme drought periods were associated with moderate declines in asthma-related ED visits (4% with one-month SPI and 3% with three-month SPI) compared to near normal periods. Extremely wet periods were associated with a decline in visits of 9% using one-month SPI. Only modest changes in asthma-related ED visit rates were seen in more moderately wet and dry periods. For one-month SPI, very dry conditions were associated with a 3% increase in

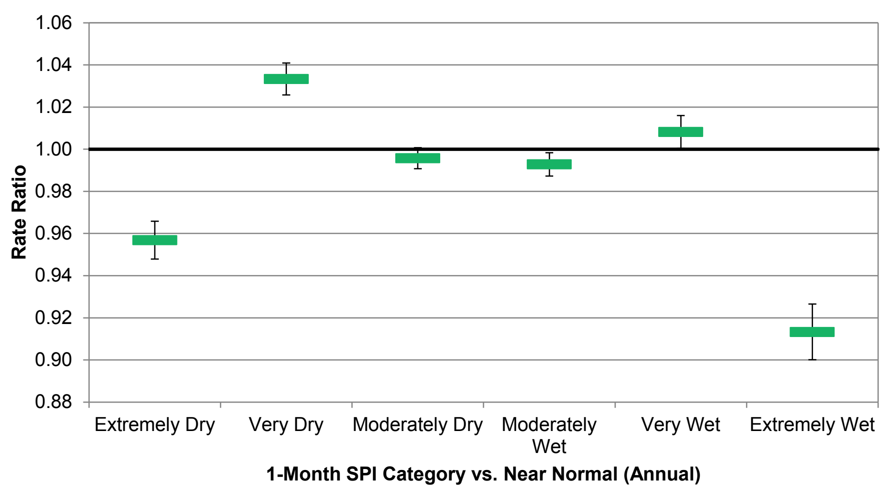

Figure 16. Associations between drought (one-month SPI) and asthma, annual, 2005-2012.

asthma-related ED rates compared to near normal conditions (RR: 1.03; 95% CI: 1.03, 1.04) (Figure 16). For three-month SPI, moderately wet and dry conditions were again associated with modestly reduced rates of asthma-related ED visits. When limiting the analysis to summer months, similar relationships were noted for one- and three-month SPI.

Respiratory Diseases (Excluding Asthma): Respiratory diseases typically have a negative association with extremely wet or dry months; that is, rates of ED visits for respiratory diseases are decreased in months classified as extremely wet or dry. For example, the rate of ED visits for all respiratory diseases was 10% less in extremely dry months compared to near normal months (RR: 0.90; 95% CI: 0.89, 0.90) for one-month SPI, and 4% less using three-month SPI (RR: 0.96; 95% CI: 0.95, 0.97). However, only 2.7% (one-month SPI) and 1.8% (three-month SPI) of months in the study period were classified as extreme drought. Moderately wet and dry periods are more common and remain protective for respiratory disease-related ED visits when examining associations with three-month SPI. Shorter-term (one-month SPI) moderately wet and very dry periods had an increased likelihood of respiratory disease-related ED visits when compared to near normal periods, and though significant, the increases were very small (Figure 17). Similar relationships were seen when limiting the analysis to only summer months for one-month SPI and respiratory diseases. However, differences were identified with three-month SPI categories. From May to October, there was a significant, though small, increase (1-2%) in ED visits for respiratory diseases in moderately and very dry months compared to near normal summer months.

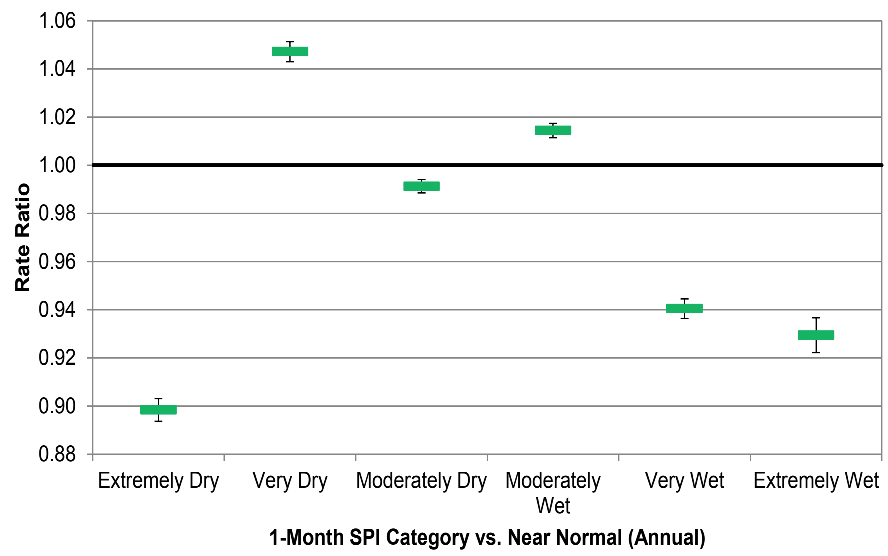

Figure 17. Associations between drought (one-month SPI) and respiratory disease (not asthma), annual, 2005-2012.

Summary Conclusions

- Florida is vulnerable to drought, despite a generally wet climate. This vulnerability may become more pronounced in the future.
- Reduction in water quality and quantity, dry air, and airborne particles during periods of drought can lead to foodborne, waterborne, and respiratory disease.
- In Florida between 2005 and 2012, more moderate drought conditions were associated with increased cases of cryptosporidiosis and giardiasis and decreased cases of salmonellosis.
- In Florida between 2005 and 2012, more moderate drought conditions were associated with increases in ED visits for all respiratory diseases, and specifically for asthma and allergic rhinitis.

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For more information on geographic, social, and medical vulnerability to hazards in Florida, please see *Climate-Sensitive Hazards in Florida: Identifying and Prioritizing Threats to Build Resilience against Climate Effects* by Emrich, C.T., Morath, D.P., Bowser, G.C., Reeves, R. at the Hazard and Vulnerability Research Institute, available at http://www.floridahealth.gov/healthy-environments/climate-and-health/index.html.

The following software was used for analysis and displaying results: Geographic Information System (GIS) ArcMAP v.10.0 (ESRI: Redlands, CA); SAS v9.3 (SAS Institute: Cary, NC); InDesign CS6 (Adobe: San Jose, CA).

Appendix I: Data Sources

Agency for Health Care Administration (AHCA): AHCA, managed by the Executive Branch of the Florida state government, is the main health policy and planning entity responsible for managing the state's Medicaid program, licensing the 41,000 state health care facilities, and sharing health care data (http://ahca.myflorida.com/). AHCA has been collecting hospital discharge and ED data since 1988 and 2005, respectively. These data sources contain a detailed record of each hospital and ED visit, and each record lists the primary and contributing diagnoses, patient demographics, and billing information. Hospital discharge data also contain information on primary and secondary procedures. Some of the strengths of using AHCA data include the following: AHCA data provide comprehensive statewide coverage and have many years of historical data available; hospital discharge and ED data provide DOH the ability to study non-notifiable diseases and injuries, and provide additional data to augment and evaluate notifiable disease information; and AHCA data provide overall and categorical health care charges that can be used to estimate cost. Limitations of AHCA data include the absence of data from federal facilities, a six-month to one-year lag in access to data due to internal reporting and validation processes, limited available identifiers, and questionable clinical accuracy as with any study relying solely on ICD-9 codes.

Florida's Notifiable Disease Surveillance System (Merlin): Merlin is a web-based surveillance system that is maintained by the DOH, Division of Disease Control and Health Protection, Bureau of Epidemiology, Surveillance Systems Section (http://www.doh.state.fl.us/disease_ctrl/epi/Acute/systems.html). It is used for notifiable disease reporting by all of Florida's 67 counties and has over 1,100 registered users. Data are collected and entered primarily by DOH staff located in the counties. Merlin is a single, statewide database with real-time web access for entering patient demographic and geographic information, case data (e.g., symptoms and exposures), laboratory results, health care visit information, extended case report form data, and control measures and outbreak information, where applicable. There are several strengths of the Merlin system that should be noted. Merlin is a flexible system that can be adapted to meet the unique needs for reporting of specific diseases through the Merlin Outbreak Module or Extended Data screens. Having statewide data on reportable diseases in Florida over the past two decades (since 1992) provides easily accessed essential background information, clinical data, and a means to view disease rates and other trends over time. The limitations of Merlin include variation in training and expertise of county staff, variable completeness and timeliness of case reporting, differing priorities for case follow-up, and differences in clinical and surveillance case definitions.

National Climatic Data Center (NCDC): The NCDC is part of the National Oceanic and Atmospheric Administration (http://www.ncdc.noaa.gov/). The NCDC is the home of a national and international archive of climatic and weather-related data sets ranging from "paleoclimatology data to centuries-old journals to data less than an hour old." The mission of the NCDC is to collect, maintain, and share these data for use by the public, industry, governments, researchers, and others. Data sources for NCDC's archives include land-based weather observation stations, satellite, radar, weather balloons, ships, and weather buoys, among many others. Therefore, NCDC data is a primary source of weather-related data for these analyses, particularly for hourly to annual temperatures and drought, but will also serve as a source for extreme event and storm reports. Most of the NCDC data used in these analyses were obtained from our collaborators/partners at the Florida State University Center for Ocean-Atmospheric Prediction Studies who conducted quality checks and post-download processing of the data for use.

Appendix 2: Discrepancies Between Reporting Sources

Please note that there may be differences between the numbers of cases of notifiable diseases reported in this Hazard and Health Profile and the DOH Bureau of Epidemiology annual Florida Morbidity Statistics Reports. For this report, we include all case classifications (confirmed, probable, and suspect) and only cases that were acquired in Florida among Florida residents, whereas the Morbidity Statistics Reports include all cases that were acquired among Florida residents, regardless of where the disease was acquired, but only those cases considered confirmed and probable. Additionally, we exclude cases when no age at diagnosis is available.

There also may be differences between the ED visits reported in this report and ED case counts or rates reported by other programs within DOH, including the Florida Environmental Public Health Tracking Network, Florida Community Health Assessment Resource Tool Set, and the Florida Asthma Program. For this report, we included all visits with a respiratory diagnosis of interest as either the primary or contributing cause of the visit, whereas in other Florida reports, only visits with a primary diagnosis may be reported.

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