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Effects of Temperature and Precipitation on Giardiasis in Missouri

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This is to certify that the doctoral dissertation by

Lori Calderas

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Abstract

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M.Ed, Secondary Education and Curriculum, Drury University 2010

BS, Biology, Drury University, 2007

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

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Abstract

Global Climate Change has empirical evidence to support the idea that CO_2 levels may be affecting weather and health, including rates of infectious diseases. The Midwest region of the United States of America has had the highest increase in giardiasis rates in recent years, and Missouri was chosen for this study as a representative state in the Midwest. There is no definitive answer as to why the rates of giardiasis have changed from 2003 – 2013. The Theory of Climate Change was used as the theoretical framework for this study. The purpose of this research was to determine whether temperature, precipitation and CO_2 levels are associated with giardiasis. A cross-sectional design was used for this study with a non-probability sample of reported cases of giardiasis for 2003 –2013, and data were analyzed using a bivariate analysis and multivariate analysis. There was a negative association between precipitation and number of cases of giardiasis in Missouri residents ($p < .05$), a positive association between temperature and number of cases of giardiasis in Missouri residents ($p < .05$), and a positive association between CO_2 levels and number of cases of giardiasis in Missouri residents ($p < .05$). Levels of CO_2 modified the association between precipitation and number of cases of giardiasis in Missouri residents ($p < .05$). Levels of CO_2 modified the association between temperature and number of cases of giardiasis in Missouri residents ($p < .05$). These results demonstrate that climatic factors impact public health significantly. The implications for social change are to have the waterways, wells, and public water tested more often, to reinforce the waterway closures with increased measures to prevent morbidity and mortality with giardiasis when possible, and to raise awareness of the climatic impact on health.

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Dedication

This dissertation is dedicated to my family. Without their unending support, I would not have been able to complete this right-of-passage. Thanks to my husband and two children (Eric Calderas, Kyla Calderas, and Carlos Calderas). I am the first in my family to receive a Ph.D., and without their belief that it was possible; I would not have believed it either. A big thank you goes to Brian and Jeane Eddy, Kyla Calderas, Carlos Calderas, and especially my husband Eric Calderas!

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Without the help and support of many people, this dissertation would not be possible. Although it is impossible to list every name of every person who helped me along the way, there are some that deserve special recognition. Dr. Chinaro Kennedy (my chair person and biggest cheerleader) and Dr. Vasileios Margaritis (my committee member) are to be thanked for the clarity and refinement of the ideas presented here. Without their help and guidance, the ideas presented here might never have come to be a complete dissertation. Thank you to Dr. Kennedy and Dr. Margaritis. Also, I would like to thank Dr. Drain from Brewer Science, Inc. for inspiring me to go after the challenging statistical work. Thanks also goes to my manager Shannon Whittle for being so understanding and considerate when I needed time to complete the dissertation. Thanks also goes to my office partner Sue Bruner for letting me vent to her during the hard times. Thanks also goes to Dr. Terry Brewer for encouraging me and all his employees to seek higher education. Thanks also goes to the Missouri Department of Health and Senior Services, the Environmental Protection Agency, and the National Climatic Data Center for providing the data used in this dissertation. Thanks also to Walden University, which provided a classroom, and working environment that allowed me to complete a dissertation while being a wife, mom, and full time employee. Finally, the biggest acknowledgement goes to my family for their continued support (Brian and Jeane Eddy, Eric Calderas, Kyla Calderas, and Carlos Calderas).

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Chapter 1: Introduction to the Study

Background

Several studies were conducted to address effect of weather on human health. More specifically, recent studies that have been conducted compare weather patterns to disease outbreaks in human societies. It has long been known that the changing of the seasons brings on different types of exposures to be aware of, but only recently have the weather patterns and the infectious disease patterns been studied together to determine if weather patterns have a statistically significant impact on the disease rates. This study was proposed to examine the weather patterns in Missouri and attempted to determine if precipitation and temperature have any effect on giardiasis to Missouri residents. It was based on the previous work conducted by other epidemiologists with similar questions concerning weather and infectious disease (Britton, Hales, Venugopal, & Baker, 2010). It was hypothesized that with increase in temperature and decrease in precipitation there will be an increase in bacteria and parasites that cause waterborne disease. This increase could also lead to an increase in human waterborne disease. The goal was to determine what affect the expected increase in temperature lead to in waterborne bacteria and parasites such as *Giardia*. This research also examined the effect of weather on human morbidity due to the water borne disease. This was done to determine if there was a relationship among weather patterns (temperature and precipitation), global climate change (CO_2 levels) and water borne disease-causing parasites (*Giardia*). Also, information was collected to determine if any group was disproportionately affected by

Giardia. Waterborne diseases can be predicted using weather patterns so many cases of morbidity and mortality caused by these waterborne diseases can be prevented.

Introduction

Giardiasis affects approximately 280 million people worldwide every year, and is considered the most common intestinal protozoan worldwide (Lujan & Svard, 2011). *Giardia* is a parasite that has several flagella that can attach firmly to the intestine wall (Tortora, Funke, & Case, 2010). *Giardia* (*Giardia lamblia, Giardia intestinalis, Giardia duodenalis*) is the cause of the disease known as giardiasis, which is a diarrheal disease (Heymann, 2008). Symptoms of giardiasis include: malaise, nausea, flatulence (intestinal gas), weakness, weight loss, abdominal cramps, and hydrogen sulfide smelling breath or stools (Tortora, Funke, & Case, 2010). These organisms can cover intestinal walls and interfere with food absorption (Heymann, 2008). Approximately 7% of the population are healthy carriers of the disease and shed cysts in their feces (Tortora, Funke, & Case, 2010; Perry, Staley, & Lory, 2002). Other known carriers are other mammal species, especially beavers (Tortora, Funke, & Case, 2010). Most outbreaks occur through contaminated water supplies, but can be caused by transfer from human to another and through contaminated food, including the fecal oral route (Heymann, 2008). The incubation period for *Giardia* is 3 – 25 days, with an average of 7 – 10 days; and is communicable the entire time of infection (Heymann, 2008). After infection, symptoms occur between 6 – 15 days and last for up to 4 days (Ortega-Pierres, Caccio, Fayer, Mank, Smith, & Thompson 2009). *Giardia* is highly resistant to chlorine, which kills most waterborne disease organisms, so boiling and filtering water is necessary to eliminate the parasite (Tortora, Funke, & Case, 2010; Perry et al., 2002). Organisms can be detected in several ways including the string test (a string is swallowed with a rubber bag on the end and pulled out hours later), ELISA tests to detect ova in stool specimens, and direct fluorescent antibody test for detecting cysts (Tortora, Funke, & Case, 2010; Perry et al., 2002). There are many asymptomatic carriers and those who are immunocompromised are most at risk (Heymann, 2008).

Biology of Giardiasis in Humans

Giardiasis is caused by the parasite *Giardia lamblia*, an intestinal parasite sometimes known as beaver fever, *Giardia duodenalis,* or *Giardia intestinalis* (Lydyard, Cole, Holton, Irving, Porakishvili, Venkatesan, & Ward, 2010). In order to better understand the interval between infection and symptoms, an understanding of how the *Giardia* parasite enters the body, reproduces inside the body, causes bodily disruption, and eventually leaves the body must be known. Understanding must also include who is mainly affected and where these infections are likely to occur in the United States of America. Finally, the response of the host organism and how giardiasis is diagnosed, treated, and prevented must be understood.

Giardiasis Life Cycle

The *Giardia* parasite has two main parts to its life cycle: a trophozoite and a cyst (Lydyard et al., 2010). The trophozoite is a teardrop-shaped organism with four pairs of flagella, two nuclei, a ventral sucking disk, median bodies, and a tough exoskeleton made up of microtubules and microribbons (Lydyard et al., 2010, pp 139). *Giardia* trophozoites have no mitochondria and no peroxisomes and do have a ventral sucking disk (Ortega-Pierres et al., 2009). Trophozoites of *Giardia* have been measured from 9 – 21 micrometers long and 5 – 15 micrometers wide; whereas cysts have been measured from 8 – 12 micrometers long and 7 – 10 micrometers wide (Lydyard et al., 2010). *Giardia* cysts are smooth and oval with an extremely resistant outer wall that allows them to survive outside a host for several months in hospitable conditions (Lydyard et al., 2010). Because the cysts can survive long periods of time outside of a host, environmental contamination with *Giardia* can lead to outbreaks due to contaminated drinking water, recreational waterways, or playgrounds or sandpits (Lujan & Svard, 2011). Further research has led to increased understanding of giardiasis.

With recent advances in genetic research, the *Giardia* genome has been sequenced. It is now known that *Giardia duodenalis* isolates A and B are the ones that infect humans, and all other known isolates are not significant in human cases of giardiasis (Lydyard et al., 2010). *Giardia duodenalis* has 7 isolates, and only A and B are infectious to humans (Ortega-Pierres, Caccio, Fayer, Mank, & Smith, 2009). *Giardia* has other host-specific species including *Giardia agilis* (amphibians), *Giardia muris* (rodents), *Giardia psittaci* (birds), and *Giardia ardeae* (birds); and none of these are known to infect humans (Ortega-Pierres et al., 2009; Lujan & Svard, 2011), so they are not further discussed in this study. The other isolates of *Giardia duodenalis* infect dogs (isolates C and D), cats (isolate F), cattle and other ungulates (isolate E), and rats (isolate

G); these also do not affect humans and are not be discussed in this study. Because *Giardia duodenalis* isolates A and B also infect other animals, these isolates could be considered a zoonosis (a disease that can be transmitted between animals and humans); with isolate B also infecting other primates and dogs, and isolate A infecting primates, dogs, cats, livestock, rodents, and many other wild animals (Ortega-Pierres et al., 2009; Lujan & Svard, 2011). *Giardia duodenalis* isolates A and B are genetically and physiologically different, which may lead to differences in infection time, infection rate, and severity of symptoms (Ortega-Pierres et al., 2009). Several studies have shown great variation in severity of symptoms between isolate types A and B depending on population genetics and immune responses (Lujan & Svard, 2011). *Giardia duodenalis* isolates A and B are the only parasites discussed in this study when referring to Giardia.

As aforementioned, cysts of *Giardia* can survive long periods outside of a host; but the trophozoite form cannot (Lujan & Svard, 2011). Both are passed through feces, and that is where the life cycle begins and ends. When something contaminated (food, water, clothing, etc.) enters the mouth of a human, the cyst is taken in and swallowed (see Figure 1). From there, the cysts opens at one end (excystation) and two trophozoites come out (Lydyard et al., 2010; Olson, Olson, & Wallis, 2002). These trophozoites migrate to the small intestine and cling to the walls of the intestine with their sucking disk, or swim about freely. The *Giardia* parasite multiplies by longitudinal binary fission and proliferates in the small intestine (Centers for Disease Control and Prevention

(CDC), 2013). When the intestine pushes the parasites toward the colon, they form a cyst and are passed from the digestive system into the environment.

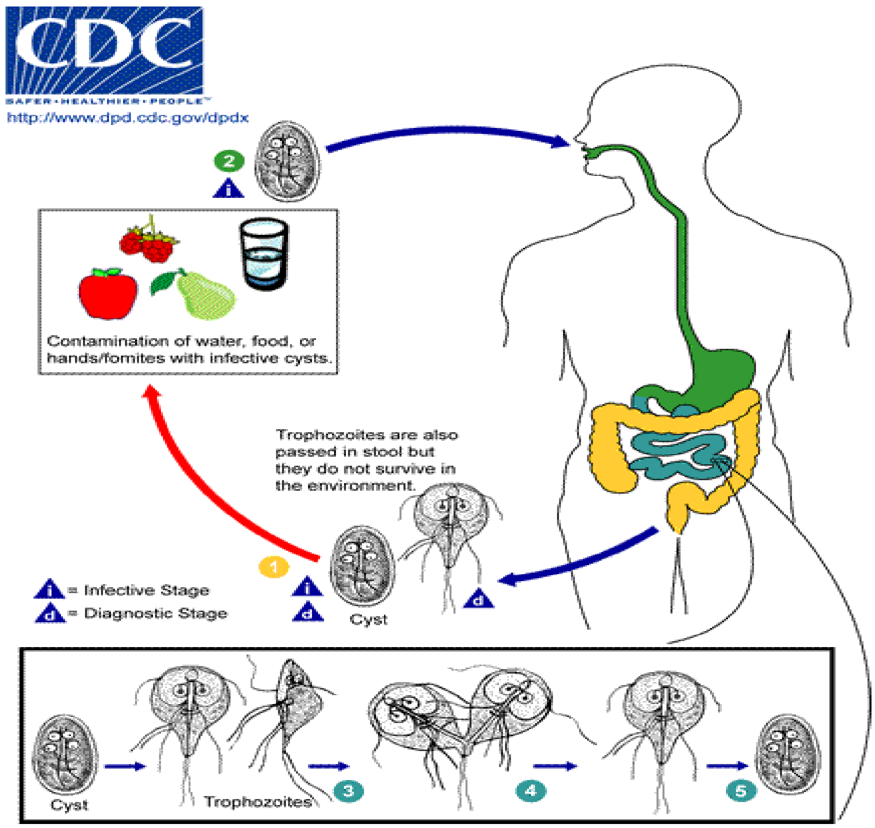

Figure 1. Giardiasis life cycle. Picture courtesy of the Public Health Image Library, #3394, Centers for Disease Control and Prevention, 2002.

Infection with Giardia

When *Giardia* was first discovered, scientists were not sure if it was a commensal organism (neither helps nor hurts host) or a parasite. Scientists such as Dobell, Miller, and Rendtorff demonstrated that *Giardia* was a parasite and not a commensal organism and contributed to malabsorption syndromes, failure to thrive syndromes, and wasting syndromes (Ortega-Pierres et al., 2009). A person must ingest a minimum of 10 – 25

Giardia cysts to become infected with giardiasis to show symptoms (Lydyard et al., 2010; Lujan & Svard, 2011). As the *Giardia* parasites multiply, they cover increasing areas of the lining of the intestinal wall (epithelium) and cause damage as they attach and detach with their sucking disk, and the intestinal wall is shed in an attempt to rid itself of the parasite (Lydyard et al., 2010; Olson, Olson, & Wallis, 2002). Sometimes the trophozoites will penetrate the intestinal wall and will migrate to other organs such as the gall bladder, pancreas, and urinary tract; but this is rare (Lydyard et al., 2010). In most developed countries, giardiasis is most common in children and travelers; but the incidence of giardiasis has increased so rapidly in recent years that it has been classified as a re-emerging infectious disease (Ortega-Pierres et al., 2009). Because intestinal parasites tend to infect the poor around the world, it was added to the World Health Organization's (WHO) Neglected Disease Initiative (NDI) in September 2004 (Ortega-Pierres et al., 2009).

Transmission to Humans

The *Giardia* parasite has long been known as a zoonosis transmitted from wild animals or farm animals to humans, although the most significant source of infection is from other humans (Ortega-Pierres et al., 2009). As aforementioned, wildlife can become infected with zoonotic strains of *Giardia* that can also infect humans. This led to the belief that beavers were the source for human cases of giardiasis in a study finding that campers were infected from water where infected beavers swam (Ortega-Pierres et al., 2009). When further examinations occurred, it turns out that the beavers only downstream from a sewage processing plant were infected with the disease; indicating giardiasis can be transferred easily from human to wildlife and back again (Ortega-Pierres et al., 2009). Similar reports have come from Gorillas in Uganda; Musk-Oxen in the northern regions of Canada, Alaska, and Russia, Norway, Sweden, and Greenland; and a farm bred species of bandicoot in Australia (Ortega-Pierres et al., 2009). The study on the Musk-Oxen was of particular interest to this study because Missouri has many cows and other ungulates. These may be an independent source of *Giardia* that can be transmitted to humans through feces runoff into wells or natural water systems, or close contact with such animals through agricultural practices. Also, a marked increase in giardiasis cases in the U.S.A. occurred from early summer to early fall in 2005, a double in numbers (Lujan & Svard, 2011), which corresponded to increases in temperature and increases in outdoor activity of Missouri residents.

There are several ways a human can ingest the *Giardia* cysts: the fecal-oral route, food contamination, water contamination, and sexual transmission. A person could not wash their hands after using the bathroom and contaminate food, water or a fomite (other than food or water thing that transmit disease like a bath toy) and then the other uninfected persons might ingest some cysts. Also, transmission via anal sex has been observed in homosexual males (Lydyard et al., 2010). The primary routes of documented exposures occur through water contamination and drinking of the cysts. Several factors contribute to water being the primary means of infection by giardiasis including: large number of cysts excreted into the environment by hosts, low infectious dose, the ability for the cyst to survive long periods of time outside the host in favorable environmental conditions, the ability of the *Giardia* parasite to infect many species, and the ability of the cysts to be carried by non-infected species to new areas; insects and birds carry on their bodies and land in new areas dropping off cysts (Lujan & Svard, 2011). Carrier status (host is infected and can transmit disease, but not affected by the disease) is not uncommon, and even if a person does not show symptoms, they may transmit it to others via a toilet seat or other commonly used objects.

Host Response to Giardiasis

Giardiasis is sometimes called “traveler’s diarrhea” or “backpackers diarrhea” because travelers to developing countries and travelers who may camp and not boil water have a higher rate of *Giardia* infection than the general population. Host reactions to *Giardia* infections differ due to variation in host immune mechanisms and non-immunological mucosal processes (Lydyard et al., 2010). The human body sheds the epithelial cells of the intestine every 3 – 5 days which forces the *Giardia* parasite to constantly have to detach and re-attach when skin cells are shed (Lydyard et al., 2010). Also, the goblet mucus helps in preventing the *Giardia* parasite from finding a suitable attachment location (Lydyard et al., 2010). Finally, other organisms (like helpful bacteria) in the intestine may help block potential attachment locations for the parasite (Lydyard et al., 2010). There is little mucosal inflammation in the human host when infected with the *Giardia* parasite, and some innate immunity such as defensis and lactoferrin, which the epithelial cells of the intestines secrete, may help defend the body against *Giardia* parasites (Lydyard et al., 2010). There is some evidence that CD4+ T cells and various antibodies may play a role in adaptive immunity of the host (Lydyard et al., 2010). Host mechanisms recognize foreign variant surface proteins (VSP) on foreign objects and then create an immune response specific to that threat. To overcome this, the *Giardia* parasite has the ability to change its VSP on its exoskeleton to avoid detection and to cope with varying microenvironments in the intestine (Lydyard et al., 2010). The *Giardia* parasite can only use one VSP at a time, but it has coded in its DNA up to 150 VSP types that it can use, which may help explain why it is so persistent in the host (Lydyard et al., 2010). Because it can change the VSP so often, giardiasis causes disruptions in absorption and digestive functions. A shortening of the villus in the intestine may cause this, or a change in the cytoskeleton of human duodenal cells leading to increased apoptosis; but these are not definitively correlated or associated with giardiasis (Lydyard et al., 2010, pp 143). It still remains unclear the exact mechanism by which giardiasis infection causes these effects.

Symptoms

Giardiasis can present in many ways, from a carrier with no symptoms, to the immune-compromised with severe symptoms and death. Up to 80 % of individuals infected with giardiasis are nonsymptomatic carriers (Ortega-Pierres et al., 2009). Symptoms occur about 1 – 3 weeks after infection. This is important to know, because when tracking down potential causes such as temperature, rain, and carbon dioxide (CO_2) variations, it was prudent to go back 1 – 3 weeks before symptoms occurred to determine a potentially causative factor. Symptoms of giardiasis include: watery diarrhea with abdominal cramps, severe flatulence, nausea with or without vomiting, fatigue and sometimes fever (Lydyard et al., 2010). Sometimes, it takes longer to show symptoms. Some other symptoms being yellowish soft loose foul smelling stools that typically float due to high lipid content; and the stools may be watery or constipated (Lydyard et al., 2010). The first symptoms usually last up to 4 days and then go away or become chronic. Other noted symptoms include: anorexia, malaise, and weight loss (Lydyard et al., 2010). Children with giardiasis can suffer malabsorption syndrome and failure to thrive and protein- losing enteropathy. These can lead to stunted growth and vitamin deficiency as most lipids are passed out of the intestines and cannot dissolve the vitamins for uptake (Lydyard et al., 2010). Children are at much higher risk than adults for long-term consequences of *Giardia* infection, such as malnutrition, micronutrient deficiency, failure to thrive syndrome, iron deficiency, anemia, and poor cognitive function (Ortega-Pierres et al., 2009, pp 4). Malnutrition, HIV / AIDS, cancer, receiving a transplant, and being elderly are high risk factors for severe reactions to the *Giardia* parasite (Lydyard et al., 2010). *Helicobactor pylori* infections may predispose human hosts to giardiasis infections (Lydyard et al., 2010, pp 144).

Diagnosis

Primary diagnosis of giardiasis is through the parasite cysts in stools; which are collected typically 3 times due to shedding of cysts variation in hosts. Another method of diagnosis through stool sample is by ELISA tests and direct fluorescence assays, which can be easily attained (Lydyard et al., 2010). Polymerase Chain Reaction (PCR) tests can also be done. A "string" test can be done in which a person swallows a string with a gelatin encased weight on it and it goes into the intestines overnight and is pulled out later the next day to examine if there are trophozoites or cysts on it. Also, there is a duodenal biopsy which snips a piece of the intestine out and looks for parasites on it – this is the most sensitive type of test for giardiasis (Lydyard et al., 2010).

Prevention

The first step in prevention is to rid those who have the parasite of the parasite. This can be done with various medications (Lydyard et al., 2010) including: nitroimidazoles (metronidazole, tinidazole, ornidazole, and nimorazole); nitrofuran derivatives (furazolidone); and acridine compounds (mepacrine and quinacrine). Metronidazole is the most commonly prescribed drug for giardiasis in the United States of America, followed by Furazolidone; although Albendazole is commonly used in developing countries like Africa because of its ability to kill worms and other types of parasites with one pill (Lydyard et al, 2010). Pregnant patients should be treated as special cases due to the potential effects on the unborn fetus. After the parasite is ridded from the host, prevention of future infections can occur through education, good hygiene, avoiding contaminated drinking water and recreational water, and taking care when visiting developing countries, and especially with water (Lydyard et al., 2010). Currently there is no preventative medicine for humans for giardiasis or vaccines; although there is a vaccine for giardiasis in dogs (Lydyard et al., 2010).

Statement of Problem

Weather patterns have been used to predict seasons of drought or flood or other disaster causing effects on the populations in which they were studied. The prediction of weather is not a new phenomenon, but its impacts on public health have not been a focus of much research, until recently. To make matters more complicated, global climate change may be affecting the number of cases of giardiasis by affecting temperature and precipitation patterns. There are several studies that indicate that the effects of weather have dramatic impact on public health (Bi, Wang, & Hiller, 2007; Chase & Knight, 2003). Missouri is prone to having four seasons of weather, which leads to increases in naturally occurring waterborne diseases if conditions are correct. In Missouri, *Escherichia coli*, *Salmonella*, *Cryptosporidium*, and *Giardia* are all waterborne diseases that are monitored by the Missouri Department of Health and Senior Services (MDHSS) and normally, *Salmonella* and *E.coli* are considered food-borne illnesses. However, due to the problem of agricultural runoff and agricultural pollution in lakes and streams in Missouri, *Salmonella*, *E.coli*, *Giardia*, and *Cryptosporidium* are carefully monitored in Missouri (MDHSS, 2012).

This monitoring was demonstrated in recent years (2010–2012) with the closing of several local waterways to all persons unauthorized to be there according to the MDHSS and the Department of Natural Resources until the water contamination decreased to an acceptable level (Centers for Disease Control and Prevention (CDC), 2012). The caseload of these diseases was expected to increase in 2012 as Missouri had an exceptionally light winter and was expected to have an extremely hot summer (MDHSS, 2012). I analyzed the morbidity and mortality of Missouri residents concerning giardiasis to determine if changes in temperature and precipitation had an effect on waterborne diseases, and if this effect was being modified by CO_2 levels, and if any group was disproportionately affected by giardiasis in Missouri.

Purpose of the Study

The purpose of this research was to determine whether temperature, precipitation and CO_2 levels were associated with giardiasis. If communal waterways of Missouri were overburdened with microbial life, and whether patterns were associated with disease acquisition, then it was predicted that waterborne diseases would affect human morbidity and mortality.

Research Questions and Hypotheses

Research Question 1

Is there an association between precipitation and the number of cases of giardiasis in residents of Missouri?

> $H_0$1: There is no association between precipitation and the number of cases of giardiasis in residents of Missouri.
>
> H_a1: There is an association between precipitation and the number of cases of giardiasis in residents of Missouri.

Research Question 2

Is there an association between temperature and the number of cases of giardiasis in Missouri residents?

$H_0$1: There is no association between temperature and the number of cases of giardiasis in Missouri residents.

H_a1: There is an association between temperature and the number of cases of giardiasis in Missouri residents.

Research Question 3

Is there an association between CO_2 and the number of cases of giardiasis among residents of Missouri?

$H_0$1: There is no association between CO_2 and the number of cases of giardiasis among residents of Missouri.

H_a1: There is an association between CO_2 and the number of cases of giardiasis among residents of Missouri.

Research Question 4

Is the association between precipitation and giardiasis modified by CO_2 levels?

$H_0$1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between precipitation and giardiasis among Missouri residents is modified by CO_2 levels.

Research Question 5

Is the association between temperature and giardiasis modified by CO_2 levels?

$H_0$1: The association between temperature and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between temperature and giardiasis among Missouri residents is modified by CO_2 levels.

Theoretical Framework

The theory used in this research was based on the theory of global climate change. Global climate change has a long-term effect on weather patterns and thereby affects temperature and precipitation in any given area of the Earth. By affecting temperature and precipitation, global climate change has indirectly affect the way that animal species behave and react to stimulus. Temperature and precipitation were affecting the number of cases of giardiasis in Missouri, so it was thought that global climate change was acting as a confounding, mediating, or determining variable in affecting infection rate of giardiasis in Missouri. Because global climate change affected the results of this research, it was important to understand it and how it had an impact on this and other research conducted concerning weather and disease.

Earth's atmosphere is the source of climate and weather, and they interact with water and earth to create and change ecosystems (Holechek, Cole, Fisher, & Valdez, 2005). Climate can be defined as the atmospheric conditions over large areas of the Earth's surface, including seasonal and annual variations (Holechek et al., 2005). Weather can be defined as the temperature, humidity, cloudiness, precipitation, and wind at a given place at a given time (Holechek et al., 2005). Global climate change has gained evidentiary support since the 1980s when scientists first discovered the "Ozone Hole" above Antarctica (Holechek et al., 2005). Scientist found a similar hole over the Arctic and measured a significant decrease in Ozone in the Ozone layer globally in recent years (Holechek et al., 2005). Scientists have reason to believe that part of the depletion of the Ozone layer is due to fossil-fuel use and other human activities, like the use of CFC's (Chlorofluorocarbons). Some of the support for global climate change and global warming comes from scientific mathematical models predicting future change based on current rates of change.

Some researchers use global warming and global climate change interchangeably, but they are two different ideas that are related to the same problem. Global warming is, "the recent and ongoing rise in global average temperature near Earth's surface, caused mostly by increasing concentrations of greenhouse gasses in the atmosphere." (Environmental Protection Agency, 2013). Global warming is causing a change in the weather and climate patterns, and is therefore contributing to global climate change. Global warming is one part of global climate change, but it is not the only part of global climate change, and therefore the terms cannot be used interchangeably. Global climate change is, "any significant change in the measures of climate lasting for an extended period of time, including major changes in temperature, precipitation, or wind patterns that occur over several decades" (Environmental Protection Agency, 2013).

Missouri Temperature and Precipitation and CO_2 Levels

Missouri is a state in the middle of the United States of America, and it is not immune to the effects of global climate change. The average temperature of the state of Missouri is increasing, as seen in Figure 2, by about 0.1 degrees F a decade. Overall, the amount of precipitation per year in Missouri is increasing 0.23 inches per decade (see Figure 3). CO_2 levels in Missouri are also increasing significantly ($r = 0.766$) according to Figure 4. This overall picture of all variables increasing did not necessarily paint an accurate picture of how this is affecting the weather throughout the year. Precipitation annual amounts have been increasing, but when paired with CO_2 levels, precipitation rates show a slight decrease from what is the expected increase (see Figure 5), although this is insignificant currently, it may increase in magnitude in the future (NOAA, 2013). Overall, precipitation seems to be unaffected, although there was a noticeable increase in precipitation in the winter months, which can be associated with global warming. As global warming increases temperature in the air, it allows air to hold more water vapor, which would give winter storms more power to increase snow, sleet, freezing rain, and other adverse weather events. Also, temperatures are not just increasing, they are getting worse on both ends of the spectrum (heat getting hotter, cold getting colder). There was a slight association with CO_2 and temperature increase in Missouri (see Figure 6). Remember that the increase in overall temperature allows more water vapor to be held in the air. Water tends to hold temperatures more constant (ex. Cold stays cold and hot stays hot). Summer temperatures are increasing (see Figure 7) and winter temperatures are decreasing (see Figure 8). This is what would be expected as a climate change event due to global climate change and global warming.

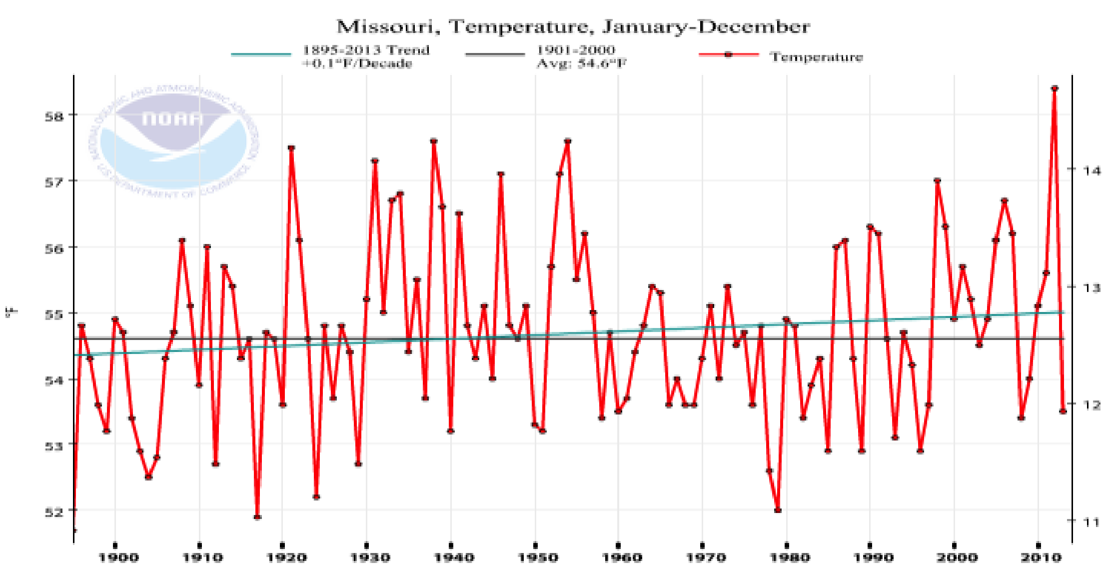

Figure 2. Missouri temperature, 1900–2012.

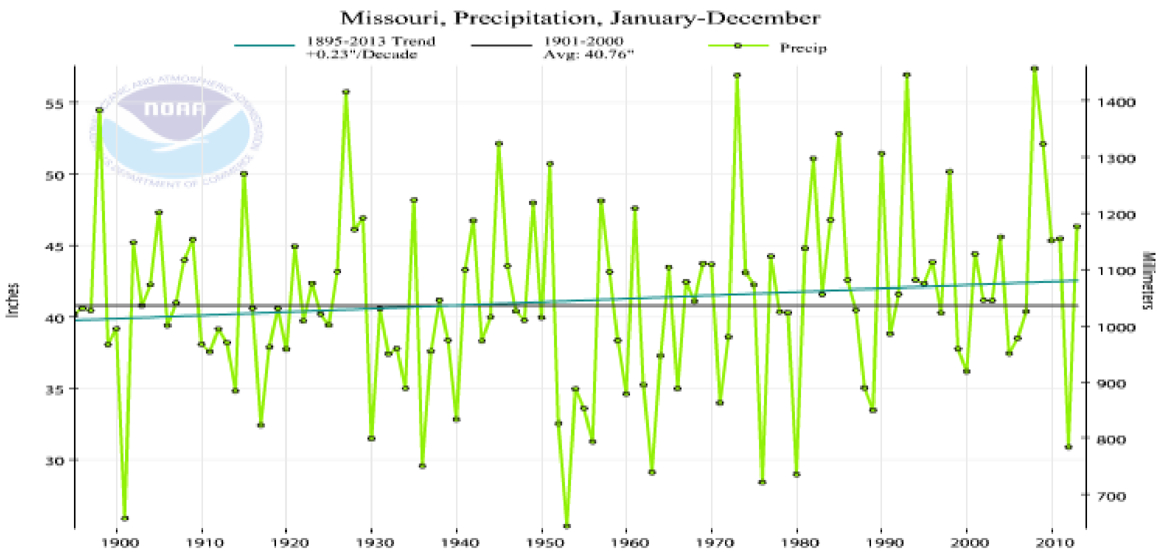

Figure 3. Missouri precipitation, 1900–2012.

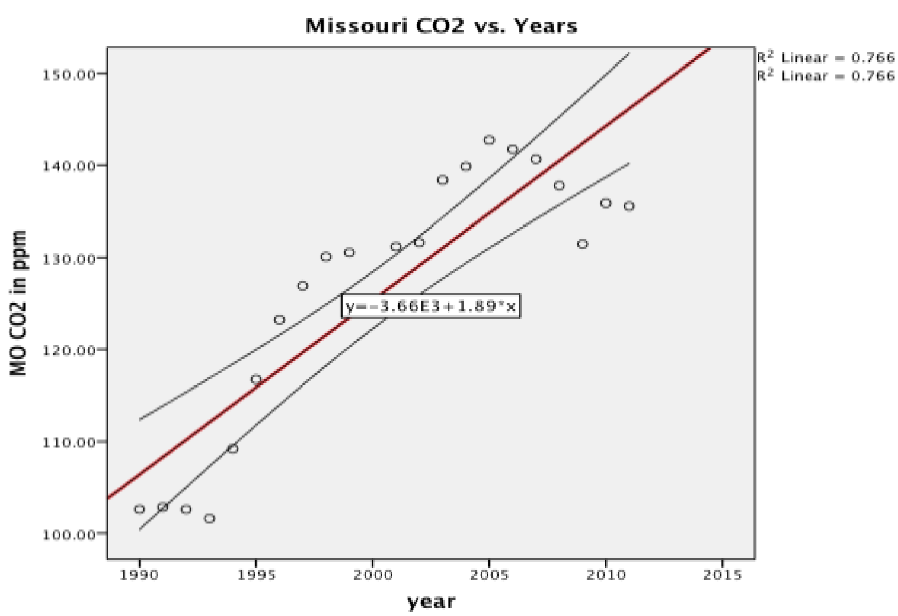

Figure 4. Missouri CO_2 vs. year, 1985 –2015.

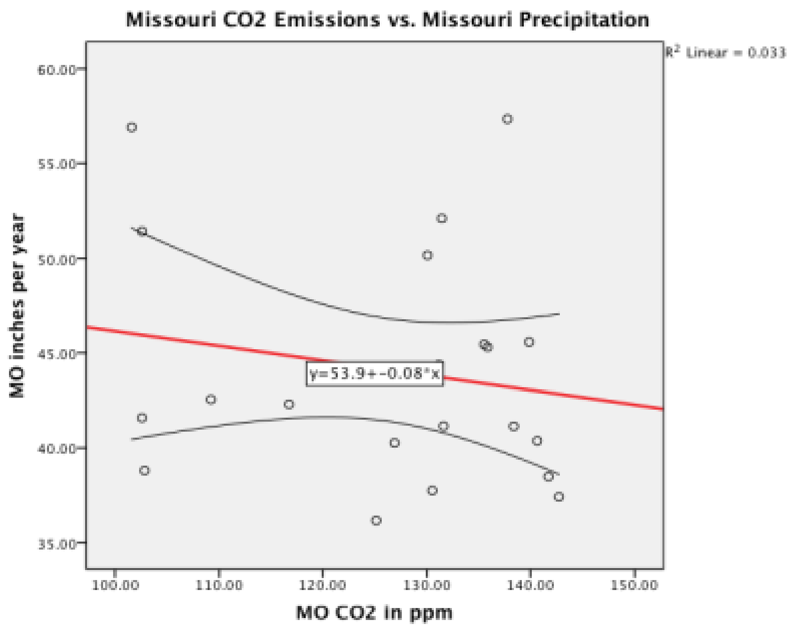

Figure 5. Missouri CO_2 vs. Missouri precipitation average, 1985 –2015.

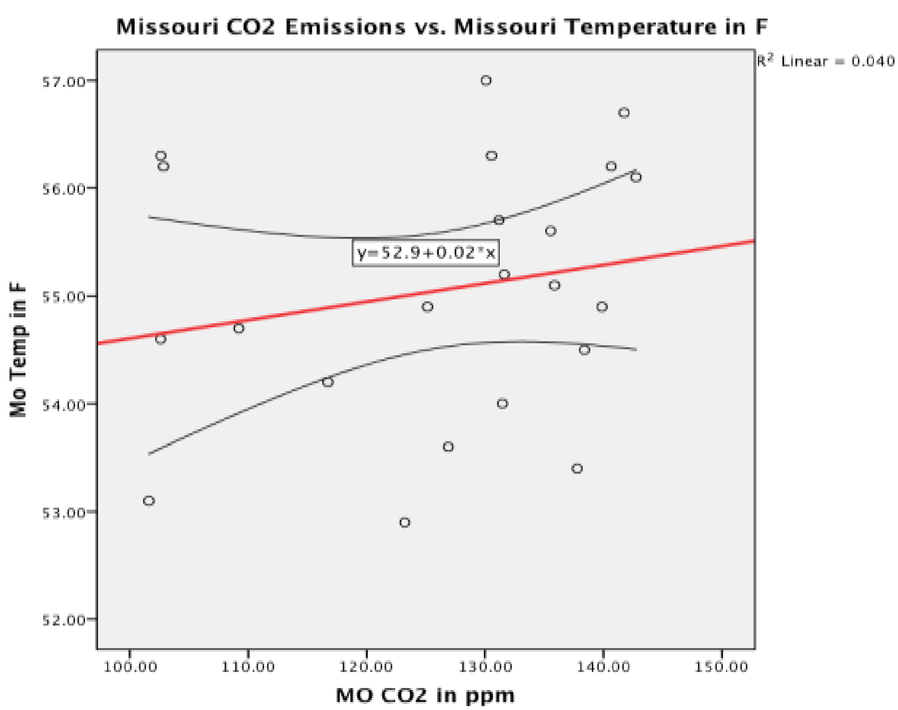

Figure 6. Missouri CO_2 vs. Missouri temperature average, 1985 –2015.

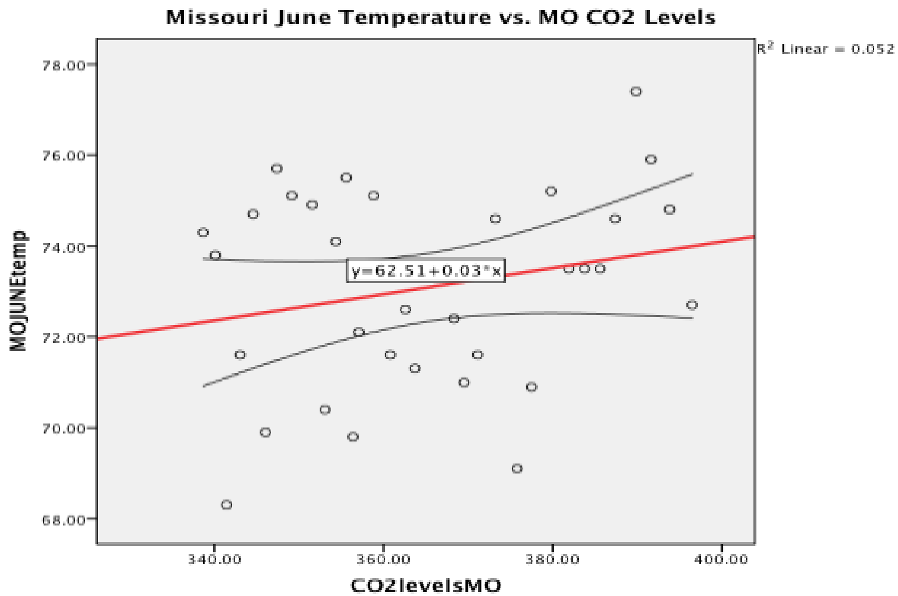

Figure 7. Missouri CO_2 levels vs. Missouri temperature in June, 1985 –2015.

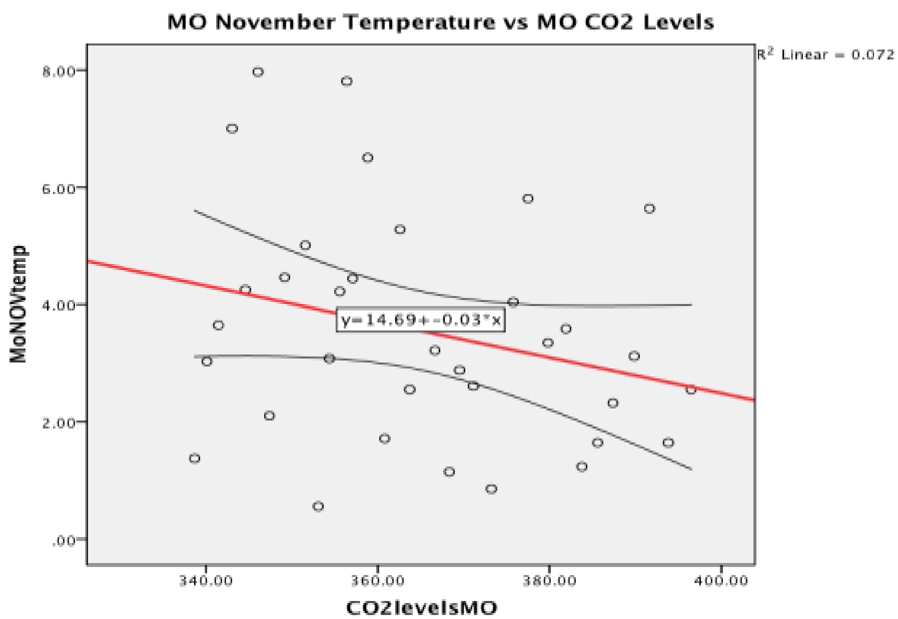

Figure 8. Missouri CO_2 vs. Missouri temperature November, 1985 – 2015.

CO_2, Temperature, Precipitation, and Giardiasis in Missouri

The State of Missouri allows a large amount of CO_2 to be put into the air by businesses, has an excess of farmland containing cows (which release methane constantly), has an excess of nitrogen compounds found in fertilizers used for crops (and burned after harvest), and is considered a tributary state because it has so many rivers, springs, and streams. As the CO_2 in the air in Missouri increases, it will have a noticeable effect on weather, triggering the water vapor, methane, and nitrous oxide in the air to accelerate their normal heating activities, leading to more severe weather events for longer durations than is considered normal and will potentially modify disease risks such as waterborne illnesses like giardiasis. Temperature and precipitation patterns are changing in Missouri, and it is only logical to think that the natural fauna of the region will have to adapt to that change to survive. As giardiasis adapts to the changes in temperature to survive, humans must be prepared to take public health action to prevent morbidity and mortality of the residents of Missouri.

In this study, CO_2 emissions in Missouri were used as a measurable value of global climate change in Missouri. Carbon dioxide emissions in Missouri were compared to cases of giardiasis, precipitation, and temperature data to determine if it was having an effect on the cases of giardiasis per month in Missouri. It was proposed that as CO_2 emissions increased, they have a significant impact on the number of cases of giardiasis in Missouri.

Definition of Terms

Missouri Resident. Missouri Resident is defined as someone having permanent living quarters in Missouri for more than 183 days of the year (Missouri Department of Revenue, 2012), or parent that is Missouri resident if below 183 days of age.

Probable Infection from Water Source in Missouri. Probable infection from water source is defined as the investigation of infection indicates probable infection is due to some form of contact with contaminated water source in Missouri.

Case definition for giardiasis. The CDC clinically defines giardiasis as, "an illness caused by the protozoan *Giardia lamblia* (aka *G. intestinalis* or *G. duodenalis*) and characterized by gastrointestinal symptoms such as diarrhea, abdominal cramps, bloating, weight loss, or malabsorption" (CDC, 2011). The laboratory criteria for diagnosis include, "the detection of *Giardia* organisms, antigen, or DNA in stool, intestinal fluid, tissue samples, biopsy specimens or other biological sample" (CDC, 2011). A probable case is defined as, "a case that meets the clinical description and that is epidemiologically linked to a confirmed case" (CDC, 2011). A confirmed case is defined as, "a case that meets the clinical description and the criteria for laboratory confirmation as described above; molecular characterization (e.g. assemblage designation) should be reported" (CDC, 2011). For the purposes of this study, all probable and confirmed cases using the CDC case definition were included, assuming Missouri residency and water borne cause.

Global warming. Global warming is defined as, “the recent and ongoing rise in global average temperature near Earth’s surface, caused mostly by increasing concentrations of greenhouse gasses in the atmosphere.” (Environmental Protection Agency, 2013).

Global Climate Change. Global climate change is defined as, “any significant change in the measures of climate lasting for an extended period of time, including major changes in temperature, precipitation, or wind patterns that occur over several decades” (Environmental Protection Agency, 2013).

Assumptions

There were several assumptions made in this study. Since secondary data were used, it was assumed that the original data were recorded correctly and transcribed correctly into the databases for temperature and precipitation and CO_2 emissions. It was also assumed that not every case of giardiasis was reported. That is why this was considered a sampling of the total cases of giardiasis from the state. It was assumed that enough cases were reported to capture a significant amount and representative portion of those affected by the disease. Also, it was assumed that the disease and personal health information was recorded, and transcribed correctly. Also, it was assumed that there was a time delay of 1 – 3 weeks from time of initial infection with the Giardia parasite and time of symptoms manifesting in the host. It was also assumed that CO_2 emissions, being used as a measure of global climate change, had an effect on the other variables of precipitation, temperature, and cases of giardiasis.

Limitations

This research had some limitations that need to be discussed. There are factors that were beyond the control of the researcher due to the nature of the cross-sectional research. Both outcome and exposure information were assessed at the same point in time. Thus, there was no way of discerning exact temporality. Additionally, data needed was obtained from several different sources. Weather data on precipitation and temperature for general observations were obtained from the National Climatic Data Center. CO_2 data has only been publically collected in Missouri since 1990, so previous data came from other reports and global CO_2 levels as taken by ice core data or Hawaii observation data. Also, giardiasis cases have only officially been recorded in Missouri for about 10 years, and the format for collecting such data changed in 2009, so there was not a direct correlation between the before 2009 data and after 2009 data on required information. This did not affect this research too much, considering required data for this research did not involve the data change that occurred in 2009. Other concerns arose when considering validity and reliability issues. The research was only as good as the data entered into it, so if data were entered incorrectly or manipulated incorrectly, the results would be false. Sampling and Methodological consideration were addressed also when discussing limitations. Since every known case in Missouri was used, sampling data were at their best possible outcome. There were always unreported cases and these may be significant enough to skew the data in the future. As global climate is changing, what weather predictions that were used in the past may not be appropriate for the future. This was something future models will need to take into account.

Significance of Study

This study was important because it examined the possible infection of Missouri residents by waterborne diseases and attempted to predict and prevent outbreaks of Missouri residents in the future. According to the CDC (Yoder, Gargano, Wallace, & Beach, 2012), the Midwest of the United States had the highest number of giardiasis cases of all regions in 2010 (n = 5,471 in 2010). An outbreak of giardiasis in Missouri could cost between $22 million and $125 million dollars when accounting for tangible and intangible assets (Harrington, Krupnick, & Spofford, 1991). The estimated total cost spent on giardiasis treatment in Missouri in 2010 was $726,853.03 dollars (Yoder et al., 2012; Harrington et al., 1991). The researcher of this study also addressed some of the gaps previously identified by focusing on Missouri and its weather patterns and waterborne diseases morbidity and mortality. The researcher of this study sought to add data and knowledge to the growing body of evidence of climate change and its effects on public health. This study needed to be conducted because Missouri waterways are used by the public and may be polluted beyond acceptable measure and become the source of an outbreak in Missouri.

Social Change Implications

The main social change implications of this research were policy change. One policy change that should occur due to this research is that because it has demonstrated that precipitation and temperature have an effect on the cases of giardiasis in Missouri, that when the temperature and precipitation are at levels conducive to the growth of giardiasis, public water recreational sites that could potentially be contaminated will be closed to the public preventing further spread of the infection. Also, many people in Missouri have water wells that provide their only source of drinking water. Further policy change should occur by having more inspections of water wells that provide water to households and businesses, especially during peak infection times for giardiasis. This will help raise awareness in the communities at risk and through the local businesses help prevent morbidity and mortality through drinking contaminated drinking water. Finally, it is hoped that local and state public health officials will use the predictive models to help predict areas of high risk for giardiasis infection and the state can then allocate resources to testing wells and closing public waterways appropriately. Basically, social change can occur from this research by informing public health officials and policy makers of the situation and making laws to keep people out of contaminated water and keep people from drinking contaminated water.

Summary

Giardiasis is caused by the parasite *Giardia* (*Giardia lamblia, Giardia intestinalis, Giardia duodenalis*) which has two variants known to infect humans. The *Giardia* parasite can survive a very long time in cold water. It only takes about 10 cysts to enter the body to cause giardiasis the diarrheal disease associated with the *Giardia* parasite. *Giardia* cannot be seen by the naked eye, and therefore, people playing in recreational waterways or drinking contaminated water would not know they are being infected. Giardiasis affects the young and elderly more severely than those of young adult to midlife adult age. Those most likely to be targeted to the point of severe illness or death by this parasite are the very young and elderly, and they need to be aware and protected by preventive measures by public health officials. The next chapters will delve deeper into the understanding of the giardiasis parasite, similar studies, and methodology used to determine if precipitation and temperature have an effect on cases of giardiasis, and how global climate change may be influencing the infection rates of giardiasis.

Chapter 2: Literature Review

Introduction

Waterborne diseases have been a threat to the health and safety of humanity since antiquity. Water borne diseases come from intake of water contaminated with microbial life (Tortora, Funke, & Case, 2010). It is not uncommon for waterborne illnesses to occur in clusters including those who visited a local lake or stream that became contaminated with microbial life (Nelson & Williams, 2007). In recent years, it has been proposed that global climate change has begun to affect local weather patterns in dramatic ways (NOAA, 2013). This would undoubtedly put selective pressures on waterborne disease microorganisms to adapt to the changing environment (Nelson & Williams, 2007).

Background

There have been several studies using the same or similar measuring instruments and index to determine the effect of weather and global climate change on human health. In these studies, one or more measure of weather, one or more measure of global climate change, and one or more measure of human health are included in an index of weather affecting health. Many of these indexes collect data from other sources that have high reliability and validity to increase validity and reliability in the study.

In one such study, researchers observed weather patterns and case counts for pneumococcal disease (White, Ng, Spain, Johnson, Kinlin, & Fisman, 2009). In this study, researchers identified associations between weather patterns and pneumococcal disease through use of an index (White et al, 2009). The index used included: measures of cases of pneumococcal disease, temperature, wind speed, relative humidity, atmospheric pressure, and rain fall (White et al., 2009). Their environmental data were collected from a weather station and their case counts were collected from local public health departments (White et al., 2009). Their data were analyzed using Poisson regression models, meta-analytic Q-statistics and meta-regression models (White et al., 2009).

In another study, researchers focused on drought and the effect it had on mosquito populations (Chase & Knight, 2003). In this study, there was an association found between drought and mosquito outbreaks in wetland areas (Chase & Knight, 2003). Their index for measurement included: mosquito larvae, soil permanence as a determination of water in the soil, precipitation levels, and competitors of the mosquitoes (Chase & Knight, 2003). All data in this research was collected by the researchers and analyzed using statistical methods including: ANOVA and Tukey's HSD.

Cryptosporidiosis and giardiasis were analyzed in a study concerning changing weather patterns (Britton, Hales, Venugopal, & Baker, 2010). Cryptosporidiosis and giardiasis are waterborne diseases that are affected by climate change according to the researchers (Britton et al., 2010). The researchers' index for measuring the impact of climate change on human health included precipitation, temperature, quality of domestic water supplies, urban-rural status, deprivation, and notification of cryptosporidiosis and giardiasis in humans (Britton et al., 2010). Their data were collected from the Census Area Unit from previous years' data (Britton et al., 2010). The research was supported statistically through the use of confidence intervals, negative regression, multivariate analysis, and various rates and ratios (Britton et al., 2010).

Research was conducted into the precipitation rate and water-borne outbreaks in human populations in the United States (Curriero, Patz, Rose, & Subhash, 2001). In this study, researchers analyzed data from 40 years-worth of data and found that about half of waterborne disease outbreaks occurred after a heavy precipitation event (Curriero et al., 2001). This also means that about half occurred when there was not a heavy precipitation event (Curriero et al., 2001). The index used in this study included: EPA reported water-borne disease outbreaks and precipitation data from the National Climatic Data Center (Curriero et al., 2001). Statistical tests performed were chi-square tests and a MonteCarlo version of the Fisher exact tests (Curriero et al., 2001).

There is a possibility that humidity levels affect Legionellosis in the human population (Fisman, et al., 2005). In this study, researchers found a high association between humidity and Legionellosis in the Philadelphia area (Fisman et al., 2005). The index used in this study included: reported cases of Legionellosis and humidity data (Fisman et al., 2005). Reported cases were collected from the public health departments and local airport weather stations and weather stations in Montgomery county weather station (Fisman et al., 2005). Statistical tests used were Poisson regression analysis and a case-crossover study approach.

Saint Louis Encephalitis (SLE) and drought were researched and suspected of being associated in another study using the concept that climate can affect human health

(Shaman, Day, & Stieglitz, 2002). In this study, researchers found that drought actually facilitates the transmission of SLE and increase in human infection rates (Shaman et al., 2002). The index in this study included: sentinel chicken infection, mosquito numbers, and meteorological data including precipitation and humidity (Shaman et al., 2002). Data were collected from the National Climate Data Center and from the Indian River Mosquito Control District Archives (Shaman et al., 2002). Statistical support for the conclusion was in the form of univariate and bivariate logistic regression and Wald's chi-square test (Shaman et al., 2002).

In another research study, researchers examined a possible correlation between weather patterns and vector borne illness of West Nile Virus infection (Wang, Minnis, Belant, & Wax, 2010). The researchers found a positive association with dry weather and outbreaks of West Nile Virus (WNV) infections in humans (Wang et al., 2010). The index used in this case included: case reports of WNV in humans and precipitation rates (Wang et al, 2010). The data were collected from the Mississippi State Health Department and county level weather stations in Mississippi (Wang et al., 2010). Statistics that supported this conclusion were standard morbidity ratio, Bayesian hierarchal models, and conditional auto-correlative models (Wang et al., 2010).

Method for Information Collection

There were several sources of data in this investigation. One source was the CDC and its morbidity and mortality counts of giardiasis in Missouri. Another source was the Missouri Department of Health and Senior Services (MDHSS), who provided numbers of

Missouri residents suffering morbidity and mortality from giardiasis between the years 2003—2013, as well as the descriptive statistics as allowed. The National Climatic Data Center (NCDC) is where the previous precipitation and temperature data for every county in Missouri for the specified time period was found. The Environmental Protection Agency (EPA) provided data on carbon dioxide in the air. Literature was found on the Walden Library Website using Ebsco host and the Thorough search engine. The EPA website, NOAA website, NCDC website, MDHSS website, and the CDC website were also used to attain data for this research. Amazon was used to attain some books on climate change and giardiasis research.

Rationale for Current Study

There are many studies where researchers examined the effects of weather on infectious diseases, including vector-borne or parasitic diseases. One such study involved the study of weather patterns on the population of rodent populations in the South-West United States and the weather patterns as they related to infectious diseases such as Yersinia pestis (plague), Dengue, Hanta Virus, and Valley Fever (Kolivras & Comrie, 2004).

The South-West United States is home to an indigenous strain of plague, which is carried by rodents and delivered to humans in times of excessive rain (Kolivras & Comrie, 2004). The reason for this is that the rats multiply greatly when there is an abundance of food. The rats then invade human homes and transmit the fleas that carry the disease from rat to human (Kolivras & Comrie, 2004). When the weather patterns were compared with rodent populations and health effects, it was discovered that when it was rainier than usual, rat population increased, and plague cases increased (Kolivras & Comrie, 2004). This pattern was discovered for other diseases as well within the same region (Kolivras & Comrie, 2004).

Climate change and its impact on infectious diseases of North America research supports the theory that weather patterns can impact the infectious capability of infectious diseases that are endemic to North America (Greer, Ng, & Fisman, 2008). The researchers in this article suggest that climate change will alter the relationship among microbes, insect vectors, animal reservoirs, and humans in infectious disease epidemiology (Greer, Ng, & Fisman, 2008, pp 716). The researchers also suggest that warmer temperatures and changes in precipitation patterns are likely to increase vector-borne and waterborne disease in North America and elsewhere (Greer, Ng, & Fisman, 2008, pp 716). The researchers presented many infectious diseases studied including E. coli, and its survival rates when weather patterns change (Greer, Ng, & Fisman, 2008). The gap in the research is that the study is focused generally around the world with diseases that may not be endemic to Missouri. This article supports the premise of the research and serves as supporting evidence that climate change and weather patterns affect microbial life in waterborne diseases.

Epstein has found that weather can be linked to some negative health effects (2005). Examples were given in the article of increases in Malaria and other diseases with great climate change. Also, examples of pollen increases and heat waves are given as examples of public health effects of climate change (Epstein, 2005). It is suggested by the author that there may be unforeseen consequences to the global climate change and change in patterns of weather (Epstein, 2005). The gap in the research here is there needs to be more observed and documented effects of changed weather affecting public health to support the hypothesis proposed. The Midwest is not clearly addressed by this article and it stands to reason there needs to be some evidence gathered in Middle America to test the claims made in the article.

Researchers conducted a study with data from the Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA/CPC) and determined that climate change could have severe health effects on many places throughout the world (Anyamba, Chretien, Small, Tucker, & Linthicum, 2006). The researchers statistically analyzed weather patterns and applied the data to determine if there could be an increase in infectious diseases of various places world-wide, including North America, South America, Africa, India, and Malaysia (Anyamba et al., 2006). Although North America was included in this study, the main focus for North America was on the South-West region concerning hanta virus and plague, and California for outbreaks of West Nile Virus (Anyamba et al., 2006). The methods used in this study could be used on a smaller scale to understand what health effects Missouri has and will face concerning the changing weather patterns. There was no mention of what effects this global climate change would have on the Midwest United States. The gap in the research provided by this article is that there is no data concerning the Middle U.S. states – specifically Missouri.

An Australian study was devised to compare precipitation events to water-borne diseases and determine if precipitation had an effect on the incidence of disease in Australia (Signor, Ashbolt, & Roser, 2007). This study focused on the cattle feces run off that could contaminate water, such as Giardia, Cryptosporidium, and Campylobacter spp. (Signor et al., 2007). This is similar to the threat of cattle feces run off faced by Missouri residents in their local waterways and water supplies. The results of the study demonstrated that after precipitation events, the incidence of water-borne diseases aforementioned increased significantly (Signor et al., 2007). In years of drought, Missouri is similar to Australia when it gets precipitation. This is because Missouri would have had long periods of time for the feces to build up and then get washed all at once to the water source when there is rain. It is proposed that during years of drought, Missouri waterways will become hyper infected with waterborne diseases due to run off and concentration of living environment for the infectious organisms. This study took place in Australia and provides a great basis for the current study. The gap in the research here, again, is that no such study has been conducted in Missouri to compare precipitation or drought conditions to water-borne illness.

Cost of Giardiasis

Using the data provided by the CDC for the total giardiasis counts, costs, rates, and percentages, it can conclusively be said that the Midwest of the United States of

America had the highest number of cases of giardiasis in 2010; $n = 5{,}417$ cases in 2010 (Yoder et al., 2012). This means that almost one third (27.2 %) of all cases of giardiasis in the United States that were reported at a rate of 11.4 in the year 2010 came from the Midwest (Yoder et al., 2012). The Midwest in this study included: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. According to Yoder et al. (2012), all regions of the United States had an increase in giardiasis rates from 2009 to 2010 (Midwest 10.3 in 2009 to 11.4 in 2010, South 6.6 in 2009 to 7.2 in 2010, Northwest 9.9 in 2009 to 10.3 in 2010, Southwest 5.4 in 2009 to 5.6 in 2010), except the Northeast (9.6 in 2009 – 9.2 in 2010).

A giardiasis outbreak could cost between $9.2 million and $55.5 million in 1984 standardized U.S. dollars, considering both tangible and intangible assets (Harrington, Krupnick, & Spofford, 1991). Accounting for inflation up to 2013, the current estimate for a giardiasis outbreak would cost between $22 million and $125 million 2013 standardized U.S. dollars (United States Department of Labor, 2012). According to the CDC in their 2010 giardiasis surveillance report, giardiasis is the most commonly reported parasite in the United States of America (Yoder, Gargano, Wallace, & Beach, 2012). This leads to the following costs: $34 million in hospitalization costs and ambulance care visits cost up to $273.00 dollars (Yoder et al, 2012). That does not include the cost of intangible assets costs. Treatment costs vary as well. For example, in 2008, 500 mg of metronidazole costs $0.30 cents, and 2 mg of tinidazole costs $18 dollars (Kiser & Paulson, 2008). Another study indicated that the per capita cost of giardiasis cases was $115 Canadian dollars and the individual cost incurred was $1089.00 Canadian dollars per case (Vrbova, Johnson, Whitfield, & Middleton, 2012). These most recent estimates fit into the cost estimate calculated by Harrington, Krupnick, and Spofford (1991).

If the CDC estimate is used, of $34 million dollars a year on average spent for all the cost of giardiasis care in the United States (Yoder et al., 2012), the cost per case for Missouri can be estimated, and for the Midwest as a whole. The cost $34 million is estimated to cover the cost for all the reported cases of giardiasis in the United States; n = 19,927 cases in 2010 (Yoder et al., 2012). By dividing the total cost by the number of cases, the estimated cost per case is $1,706.23 dollars. If the estimated cost per case is multiplied by the Missouri case number for 2010 (426 cases) that results in an estimated cost of $726,853.03 dollars total spent on healthcare for treatment of giardiasis in Missouri. That may not seem like much, but when the average median income for Missouri is $44,306 per household (Missouri Economic Research and Information Center, 2013). If the cost per case ($1706.23 dollars) is multiplied that by the number of cases in the Midwest for 2010 (5417 cases) that results in an estimated cost of $9,242,635.62 dollars total for healthcare cost spent on giardiasis cases in the Midwest. By preventing outbreaks of giardiasis, people can save money, time, and stress.

Relevance to Missouri

This study is relevant and pertinent to Missouri residents and Missouri public health professionals because it directly impacts their health of the communities served by public health departments. This study could be used as a model for other studies to be conducted in other states or countries. There is a statistically significant relationship among temperature, precipitation, and CO_2 levels, and giardiasis infection rate of Missouri Residents with waterborne infectious disease, and this can allow public health professionals to predict impending outbreaks and epidemics of waterborne diseases. It will also allow them to implement Social Change policies to prevent and protect Missouri Residents from morbidity and mortality caused by waterborne diseases.

Giardiasis and Global Climate Change

Giardia cysts can persist for long periods of time, which lead to the idea that extreme weather conditions such as excessive rains, or temperatures may be a key in understanding how humans are infected with giardiasis and one key to preventing their morbidity and mortality. The *Giardia* parasite may be adapting due to ecological selective pressure to be able to survive in more extreme weather conditions, therefore giving it an edge over previous decades of *Giardia* parasites. Climate change brought about due to an increase in greenhouse gasses was found to be affecting the infection rate in Missouri; and it may also be putting evolutionary selective pressures on this organism leading to a change in infection rates than has been seen before. The amount of greenhouse gasses is monitored in Missouri, although not well regulated, and this was a way to determine if there is an effect of global climate change affecting the infectious rates in humans in Missouri over the past decade. The rate of infection of giardiasis was affected by temperature and precipitation; therefore, global climate change could worsen this situation and cause more extreme weather events leading to worse outbreaks of giardiasis in Missouri. This research investigated if giardiasis cases have been affected by temperature or precipitation in Missouri, and if global climate change also affected the infection rates of giardiasis or this potential association.

History of Climate Change Research and Theory

Climate can be defined as the weather patterns over a region for an extended period of time. The Earth is a constantly changing ecosystem, and over time, weather patterns over regions change. This change usually takes hundreds of years, giving living creatures in the region time to adapt. Sometimes, in the history of the Earth, there have been dramatic and rapid changes in climate that happen within a decade or two and change the climate of the region for extended time periods. When this happens, many creatures must migrate, find a way to adapt, or die out. Within the past 50 years, the Earth has been warming at a faster rate than in the previous centuries. That fact combined with the fact that on average, the temperature of the Earth is warmer than it has been for over 100,000 years; Earth is expected to see (and is experiencing) effects of rapid global warming in terms of global climate change.

The idea of global climate change caused by global warming is not a new idea. The first Industrial Revolution occurred and during that time weather and climate data began being kept including CO_2 levels in the atmosphere (290 parts per million 1800) and average global temperature (1850 13.6), according to the American Institute of Physics (2013). In fact, the global warming debate first started in 1859, when Tyndall found that some of the gasses in the atmosphere stop infrared radiation from reaching the surface of the Earth; he then suggested that changes in the atmosphere could bring about global climate change (American Institute of Physics [AIP], 2013). Between 1870 – 1910 the second Industrial Revolution occurred which included more industrialization of cities, increase in fertilizer use, electricity use, and public health advancements, which allowed more people to survive into adulthood (Weart, 2003). Several years later (1896 – 1897) Arrhenius calculates the amount of global warming from humans CO_2 emissions; and Chamberlin publishes a model for carbon exchange and feedback loops on a global scale (Weart, 2003). After that, World War I occurred and the Texas and Middle East oil fields were discovered and cheap energy became the norm (AIP, 2013).

In the 1930s one of the first recorded global warming trends was published; and Milankovitch suggested that ice ages were caused by orbital changes (Weart, 2003). In 1938 Callendar suggests that global warming is occurring due to increased CO_2 (AIP, 2013). Then World War II occurred and after that, the Navy began to fund many scientific research projects, some of which were to study global climate change (Weart, 2003). Several important discoveries happened in the 1950s including: Ewing and Donn propose a feedback model for quick ice age climate change, Phillips used a primitive computer to make a model of the global atmosphere, Plass worked on radiation balance of the atmosphere and said adding CO_2 to the atmosphere would affect radiation reaching surface of the Earth, Revelle studied ocean sinks and discovered that CO_2 produced by humans was too much for the oceans to absorb effectively, and telescopes show how the greenhouse effect works on Venus and is maintaining high heat without cooling (AIP, 2013).

The 1960s also showed a lot of research connecting the dots of global warming and how they work together to drive global warming. First, Keeling reports CO_2 levels in the atmosphere are on the rise and the global temperature is 13.9 C (Weart, 2003). Next calculations reveal that CO_2 levels in the air combined with water vapor can make climate sensitive to changes (AIP, 2013). Then Lorenz and fellow scientists point out that climate systems are capable of sudden shifts (AIP, 2013). In 1966, Emiliani analyzes deep-sea cores and Broecker analyzes ancient corals and both come to the conclusion separately that small orbital shifts can have a big change in climate (Weart, 2003). Next, Manabe and Wetherald calculate that doubling CO_2 would raise the temperature of the Earth up to 2 degrees Celsius (Weart, 2003). Then studies indicate possible Antarctic ice sheets (on land) could collapse and raise sea levels, and Budyko and Sellers publish information about ice-albedo (light reflectivity) feedbacks and give warning about global warming (AIP, 2013). In 1969, the world is shown a picture of Earth from space and people begin to see the Earth as a single place out in space; Nimbus III (satellite) starts taking global atmosphere temperature readings (AIP, 2013).

In 1970, the National Oceanic and Atmospheric Administration was started, and begins an aggressive funding of climate research (AIP, 2013). In the early 1970s, it was discovered that aerosols produced by humans were increasing rapidly in the atmosphere, Mars used to have a different climate than it has now, and ice cores show more evidence of rapid climate change in-between periods of stability (Weart, 2003). There were several droughts in Africa, India, Ukraine and other places that caused a world food crisis, as well as prices on oil going up caused an energy crisis (Weart, 2003). In the mid-1970s, trace gasses from airplanes are found to harm the Ozone layer; Manabe recalculated global temperature increase with new variables to show increased CO_2 raises temperature several degrees; new studies show CFC's, methane, and Ozone contribute to the greenhouse effect; deep sea cores show orbital changes affect climate, deforestation was shown to affect the carbon cycle and increase global warming; and Eddy demonstrated sun-spots affect temperature of the Earth in cycles, beginning of El Nino- La Nina (AIP, 2013). In the late 1970s scientific opinion was swinging toward global warming as a major concern for the next century, a second energy crisis motivated research in renewable energy, and the U. S. National Academy of Sciences publishes a report confirming that doubling CO_2 in the air will raise temperatures up to 4.5 degrees C (Weart, 2003).

In the 1980s there began to be a backlash against global warming theories and some conservative parties began forming coalitions to counter arguments of global warming. In the early 1980s, Greenland ice cores showed that rapid climate change can occur within a century, and the U. S. National Academy of Sciences and the Environmental Protection Agency (EPA) defended global warming (AIP, 2013). In the mid-1980s, Ramanathan and fellow scientists warned that global warming was happening faster than predicted due to greenhouse gasses; Villach Conference said global warming is inevitable and asked governments to restrict emissions; scientists linked CO_2 changes to temperature changes in Antarctic ice cores; and Broecker researched North Atlantic Ocean currents and discussed how changes in ocean currents can cause global climate change (Weart, 2003). In the late 1980s, the Montreal protocol of the Vienna Convention called for restrictions on Ozone-depleting gasses; the Toronto conference called for limits on greenhouse gas emissions; the Intergovernmental Panel on Climate Change was formed; ice core and biological studies gave support to the fact that living ecosystems contribute to climate feedback loops, and if mismanaged could accelerate global warming; and the Global Climate Coalition was formed to counter arguments from the Intergovernmental Panel on Climate Change (AIP, 2013).

In the 1990s there was much social and political change occurring around the world on opinion and desired actions concerning global warming and climate change. In the early 1990s, the Intergovernmental Panel on Climate Change released its first report confirming global warming and suggested the trend is likely to continue; scientists used global climate change models to predict slight cooling after the Mt. Pinatubo explosion, which gave further credit to the global climate change predictive models; scientists show that methane in liquid and frozen form at the bottom of the ocean can rapidly escape and increase global warming when ocean temperatures rise; studies of ancient climate confirm predictions made by global climate change computer models; Rio de Janeiro UN Convention on Climate Change put together framework for future regulation, but U. S. opposed it; and Greenland ice cores suggested climate change can happen in as little as a decade (Weart, 2003). In the mid-1990s, the Intergovernmental Panel on Climate Change released its second report which indicated human produced acceleration of global warming; and several reports showed the melting and breaking up of portions of the polar ice caps began to sway public opinion (AIP, 2013). In the late 1990s, the Kyoto Protocol was organized setting limits for greenhouse gas emissions, signed by most industrial nations except the US; Toyota introduced the Prius and made progress on large wind turbines and other renewable energy sources; computer models support is increased by correctly using models to predict patterns in ice age cores that were found to be accurate; El Nino weather paired with global warming caused warmest year to that date (1998) and an increase in weather disasters; borehole data showed evidence of unprecedented warming trend; and Ramanathan discovered the “brown cloud” of aerosol smog over southern Asia (Weart, 2003).

Since the year 2000, there has been paradigm shift surrounding global warming and global climate change, and action has been taken by many to decrease impact on environmental contribution global warming and global climate change. In the early 2000s, the Global Climate Coalition disbanded as they no longer want to fight the evidence of global warming; several biological studies indicated the importance of the biofeedback loops in the carbon cycle; the Intergovernmental Panel on Climate Change published its third report stating global warming was occurring at an alarming rate and there will most likely be severe consequences; Bonn meeting occurred with most countries working toward methods to comply with Kyoto Protocol and establish regulations; computer models accurately predicted warming in the ocean bottom, which gave further support for global warming; scientist observed that land ice melting on Greenland and Antarctica raised sea levels faster than predicted; and in 2004, the first major increase in books, movies, and art about global warming become mainstream (AIP, 2013). In the mid-late 2000s, the Kyoto treaty went into effect (2005) signed by all major industrial nations except the USA; hurricane Katrina and other storms increased scientists interest of global climate change on severe weather events and occurrence; scientists conclusively determined that the level of global warming seen in recent decades could not be due to solar variation alone; “An Inconvenient Truth” documentary was released and increased political and social awareness of global warming and global climate change; the Intergovernmental Panel on Climate Change released its fourth report which stated serious effects of global warming were already occurring and the cost of reducing emissions would be less than the cost of not reducing emissions; and Greenland and Antarctic ice sheets were melting faster than predicted (AIP, 2013).

In this decade, there have been several studies linking an increase in natural disasters such as heat waves, droughts, extreme precipitation events, floods, and other natural disasters to global warming and global climate change (AIP, 2013). The current average level of CO_2 in the atmosphere is around 394 parts per million; and the average global temperature is 14.6 degrees C, which is warmer than it has been for thousands of years (AIP, 2013).

Causes of Global Climate Change

Some causes of global climate change include increasing global surface temperature, the greenhouse effect, changes in the solar energy reaching Earth's surface, and the reflectivity of Earth's surface (Environmental Protection Agency, 2013). The surface of the Earth is heated from below, by internal combustion, and above by sunlight (radiation). The internal temperature of the Earth has not significantly changed over the past 1000 years, although it is slowly cooling, the rate is not significant compared to the change from above ground temperature changes. Above ground, the Earth is heated by solar light radiation from the Sun. The Earth is tilted and rotates on an axis. When the tilt of the Earth is away from the Sun, it is colder, and when it is tilted toward the Sun it is warmer. The Earth also orbits the sun in an elliptical orbit and not a perfect circle. The Northern hemisphere of the Earth is actually closer to the Sun in winter, but because of the tilt of the Earth, the Northern hemisphere experiences less solar light and radiation heating, so it experiences cold weather during the winter months. The northern part of the Earth and southern part of the Earth, therefore experience more seasonal change than those in the middle or near the Equator. This is a small annual example of the importance of the surface heat impact on climate.

Several factors influence surface temperature other than the tilt of the Earth and its relative location on its orbit around the Sun. The Earth has several layers in the atmosphere around the Earth's surface that protect it from the harmful effects of the Sun's ultra-violet (UV) radiation, but allow the heat to penetrate. The atmospheric layers act like a sunscreen for the Earth. One of the most important layers of protection is called the Ozone layer. The Ozone layer is made up of several trillions of O_3 molecules and they absorb the Sun’s UV radiation and allow the heat to pass through. Ozone is a good thing when it is high in the atmosphere above the Earth’s surface protecting the Earth from the Sun’s harmful UV radiation, but if ozone is at the surface in the breathable air zone, it is toxic. Ozone is an unstable triangle shaped molecule that takes a long time to form and is easily broken because the angles of the bonds. Oxygen would rather bond with other molecules and have different angles than the triangle bond formed in O_3. That is why when humans introduced chlorofluorocarbons (CFC’s) into the atmosphere and the use of nitrous oxide (N2O) products began being used in fertilizers regularly in the second half of the 20^{th} century, a significant depletion in the Ozone layer was first noticed. When chlorofluorocarbons and nitrous oxide products break down they release chlorine, fluorine, and nitrogen waste. These chemicals are carried up by wind to the Ozone layer and start breaking apart the Ozone molecules, and once they break up one molecule, they continue on to another Ozone molecule. For an example of how destructive these molecules are, “One chlorine molecule can break apart more than 100,000 Ozone molecules” (EPA, 2010). Without the protection of the Ozone layer, the Earth will be exposed to more and more of the harmful UV radiation from the sun. This means the overall temperature of the Earth’s surface will increase due to being exposed to more UV radiation.

The increase in surface temperature from UV radiation from the sun is not the only thing causing the temperature of the atmosphere of the Earth to rise. Another factor in the global warming equation is the greenhouse effect. When a car is left out in the sun on a hot day without cracking the windows, the temperature inside rises faster than outside, and that is the greenhouse effect on a small scale. The temperature is hot outside, but the temperature inside the car is hotter. This is because as gasses heat up, they expand and move faster; and as they move faster, they affect the other molecules around them to move faster. If they have no way to escape the confined space, they will continue to heat up until the sunlight putting UV radiation (energy) into the system decreases or goes away. The same thing is happening with the Earth as happens to cars in the sunlight. The air molecules are heating up and causing other air molecules to move faster and heat up as well.

One reason for the increase in UV radiation (energy) entering the system is depletion of the Ozone layer, but another reason is that there is decreased ice and snow cover on the Earth. A simple experiment shows how this works – put a white piece of paper and a dark blue piece of paper next to each other and put a thermometer on both. After about 15 minutes, a noticeable temperature difference can be seen between the two pieces of paper. This is because darker colors absorb more light (UV radiation – heat energy) and lighter colors reflect more light. As the Earth heats up because of the increase in UV radiation getting through the Ozone layer, ice melts faster. As the ice on the surface of the Earth melts, there is less white color on the surface of the Earth to reflect the light and heat. This means there is more color part of the Earth showing that will absorb and hold more heat. Clouds also reflect the UV radiation and heat, but in recent years, there has been a decreasing trend of cloud cover on the surface of the Earth (EPA, 2013). This causes the heating of the surface of the Earth to increase.

The process of heating is made faster by a few gasses that are known to cause heating to increase, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O). These gasses are classified together as greenhouse gasses because the more of them there are in the atmosphere, the more heat will be trapped in the atmosphere. They increase the greenhouse effect exponentially by trapping the reflected energy (light – UV radiation) and keeping it in the atmosphere and not letting it escape, as it would do otherwise. As the number of humans on Earth has increased, so has the amount of CO_2 in the air from burning of wood to combustion engines to coal power plants. Also, as new fertilizers have come into play, that allow farmers to put nitrogen back into the soil, the N_2O in the atmosphere has increased.

Methane is produced in many ways, but one of the ways that is directly associated with global warming is the methane seeps under or at the bottom of the oceans. Methane also can come from large garbage landfills and cows. At the deep pressures and cold temperatures of the ocean bottom, methane becomes a liquid and sometimes freezes. Since methane in gas form is a greenhouse gas, it has a detrimental effect on global temperature when the oceans heat up and release methane from its frozen or liquid state and change it to its gaseous state. This warmed up methane bubbles to the surface and floats up into the atmosphere trapping heat and increasing the greenhouse effect.

A final greenhouse gas not mentioned above is water vapor (H_2O). When the surface of the Earth increases, more water can escape liquid form and enter the air as water vapor. When this happens, it increases humidity in the air, and also holds heat in the air. Water vapor is not the same as the gasses above, because it enters the air naturally with an increase in temperature, and not due directly to human production or activity.

The combination of all the aforementioned greenhouse gasses and water vapor are causing the Earth to hold more heat in the atmosphere and surface than in the previous century. It is also causing a noticeable and significant change in the rate of heating of the Earth, which is global warming. All of this warming of the Earth has led to changes in the climate of the Earth, known as global climate change.

Effects of Global Climate Change

Indicators of global climate change include, but are not limited to: greenhouse gasses, temperature, precipitation, ocean temperature, sea level, glacier melt, sea ice melt, snow cover, length of growing season, and bird wintering ranges (Environmental Protection Agency, 2013). According to the National Aeronautics and Space Administration (NASA), arctic sea ice has decreased 11.5 % per decade since 1980, carbon dioxide is increasing 398 parts per million each year since 1960, sea level is increasing 3.16 millimeters per year since 1993, global temperature is increasing 1.5

degrees Fahrenheit since 1880, and land ice is decreasing at a rate of 100 billion tons per year (National Aeronautics and Space Administration, 2014).

Arctic sea ice. It has been observed that the sea ice cover time in the Arctic has decreased over the last decade by at least two weeks (Holechek, Cole, Disher, & Valdez, 2005). There has also been a 40% decrease in summer ice thickness in the Arctic region (see Figure 9) as well as a 10% reduction in total sea ice area in the Arctic region over the past two decades (Holechek et al., 2005). Sea ice is a reflector of UV radiation and helps keep the Earth cool. As the sea ice melts, then the Earth's surface will absorb more of the UV radiation from the Sun and temperature of the oceans and surface of the Earth will increase. This will lead to an increased greenhouse effect and changes in the climate. Ocean currents regulate most of the Earth's climate, and if too much cold water being entered into them disrupts them, drastic climate change is in store for the entire Earth.

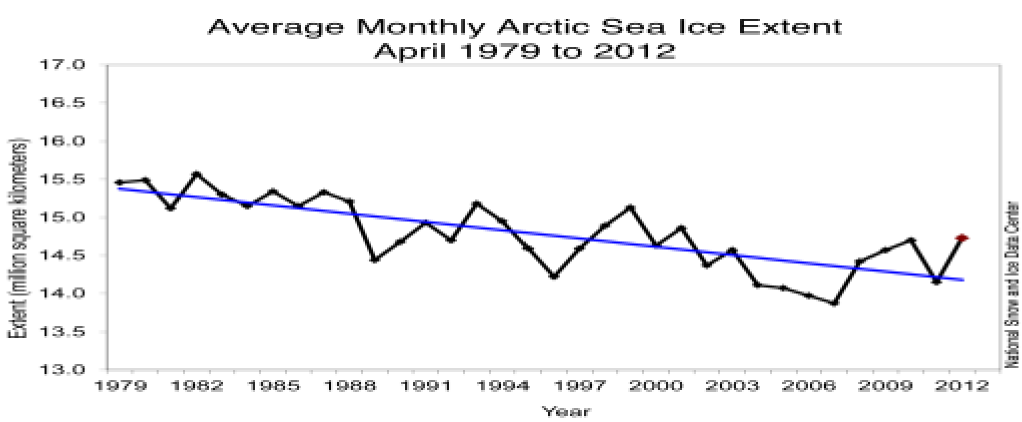

Figure 9. Arctic sea ice vs. year. Graph from National Snow and Ice Data Center. (http://nsidc.org/arcticseaicenews/2012/05/): "Image/photo courtesy of the National Snow and Ice Data Center, University of Colorado, Boulder."

Global glacial ice. Worldwide, it has been noted that glaciers south of the Polar Regions are retreating at an alarming rate (Holechek et al., 2005). This is an issue of concern for many reasons. Glacial ice provides freshwater for drinking and other human activities for millions of people around the world, and as these glaciers melt, it is uncertain where these populations will find water when the glaciers are gone. Another problem with the glaciers melting is that they provide water to the ecosystems that are built around them. As the water disappears, so will the ecosystem built around it. Finally, glaciers are huge expanses of land ice that reflect a great deal of the UV light (radiation – energy) from the Sun. As they disappear and the colored part of the Earth (land) increases, more energy from the Sun will be absorbed. This will increase surface temperature of the Earth and also increase the rate of melting of the glaciers (see Figure 10). The melting of land ice is critical also because it will contribute to an increase in global sea levels. Arctic sea ice is ice that is already added to the ocean, and if it melts it will not increase the ocean levels. Land ice is going to add more to this and increase the ocean levels. An example of this is to think of a glass of water (ocean) with ice cubes in it (sea ice). If the ice cubes in a glass of water melt, the level of the water does not increase. If you add melted water from another source (land ice – glaciers) to the glass of water (ocean), the level of water will increase. This is why glacial ice melting is a critical factor in ocean sea levels rising and sea ice melting is not. Sea ice melting can and will affect global ocean currents, and that in combination with glacial ice melt increasing the sea levels, will have a global impact on climate.

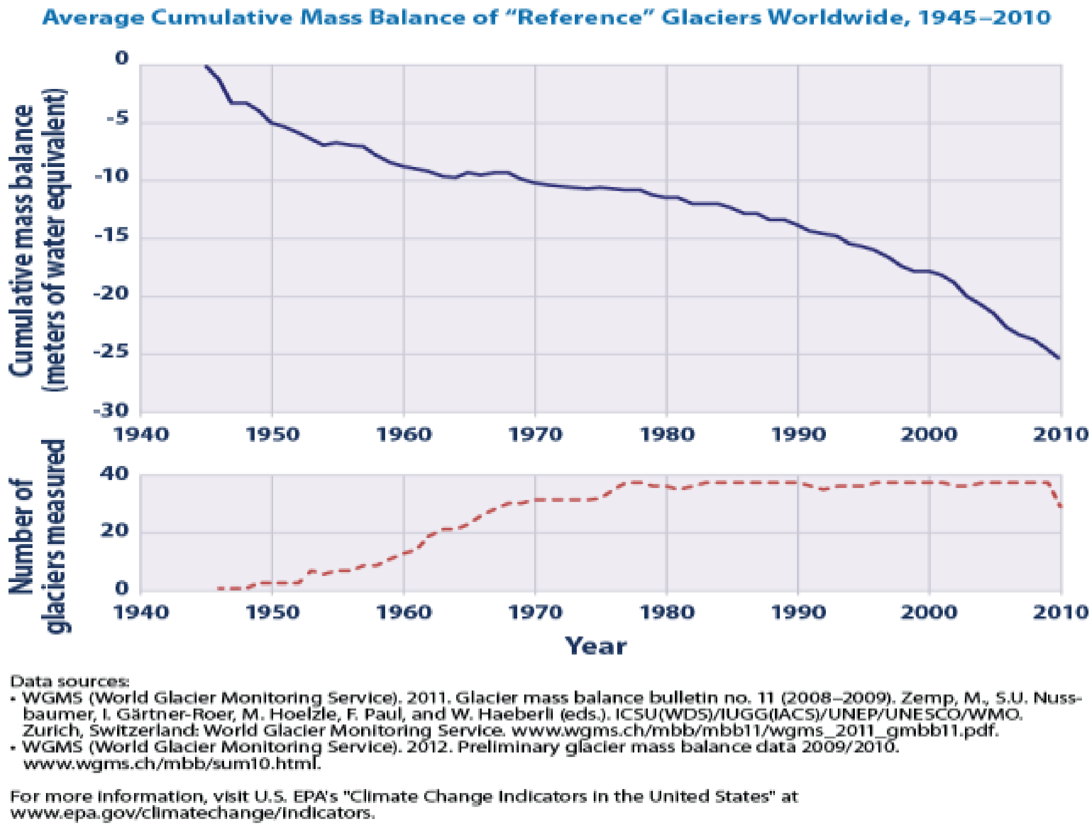

Figure 10. Glaciers mass vs. years. Graph from the EPA website.

(http://www.epa.gov/climatechange/science/indicators/snow-ice/glaciers.html)

Global sea level rising. Sea levels have been rising at a faster rate this century (see Figure 11) than the last century (Holechek et al., 2005). As sea levels rise, they increase the darker color of the Earth's surface, which will increase the Earth's ability to absorb UV light energy (radiation – heat). This will cause the oceans to heat up and release stored greenhouse gasses that are stored at the deeper places in the ocean. The deeper places in the oceans have higher pressures and colder temperatures and can serve a storage place for greenhouse gasses such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). When these are heated, they take a gaseous form and bubble to the surface contributing to greenhouse gasses in the atmosphere. Also, as the oceans heat up, they will release more water to the air in the form of water vapor, which is also a powerful greenhouse gas.

Because ocean currents rule much of the Earth's climate, as those currents become disrupted because of cold water being added from melting sea ice, and ocean levels increase because of glacial melting, and the ocean in general heats up, the precipitation and weather patterns over the entire Earth will change. Seasons will change and the warming and freezing of the Earth will change. As the oceans increase in water, they will also increase in acidity. This will cause drastic changes in the marine ecosystems that many humans depend on for survival. Also, the sea levels will rise, destroying many areas of low lying land near the ocean and displacing thousands of human and animal species.

Another effect of the oceans heating up is that Earth's land will experience higher temperatures and increased droughts. Not only will there be a general warming effect, but this warming effect will cause the severe weather events, such as tornadoes, hurricanes, tsunami's, floods, and other weather events to be more severe in nature, and there to be more of them. This is because there will be more water vapor in the air leading to an increase in energy being held in the air, which these severe weather events need to get momentum. If there is more energy put into a severe weather system, the weather will increase in magnitude and occurrence. Increased temperature also means that many species, vectors, and diseases that belonged only to tropical regions could begin to migrate North and South to regions where they did not naturally occur prior to this increase in temperature.

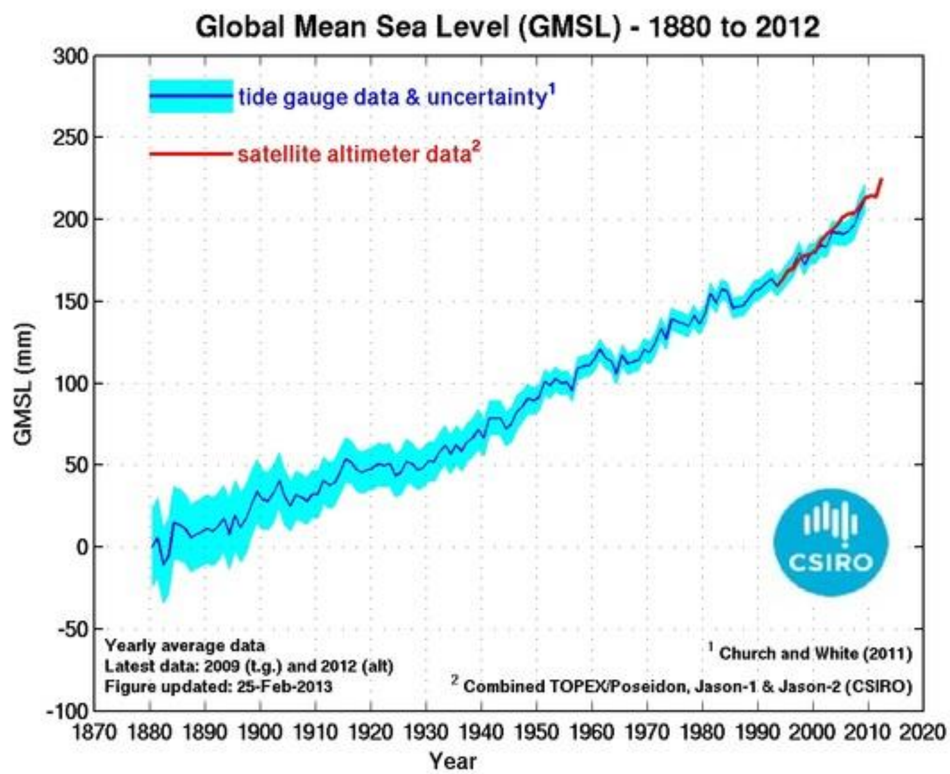

Figure 11. Global mean sea level vs. year. © Copyright CSIRO Australia, (February 25, 2013).

Graph from CMAR website (http://www.cmar.csiro.au/sealevel/index.html): Neil White last modified February 23, 2012.

Global temperature increase. One of the predictions from scientists studying global climate change is that the total temperature of the Earth's surface will increase 3 degrees C over the next century, which is a much higher rate of change from the previous century's recorded increase of 0.6 degrees C (Hoolechek et al., 2005). Ten out of the 11 hottest years on record happened from 2002 – 2013 (see Figure12); and only one year (1998) made it on to the 11 hottest years chart; and this data has been collected since 1880 (National Oceanic and Atmospheric Administration [NOAA], 2013). The year 2010 was the hottest year on record up to 2013 and it was 1.19 degrees F above the average temperature as determined by previous data; and all the 11 hottest years were at least 1.03 degrees F above average temperature (NOAA, 2013). The year 2013 was the 37th consecutive year that temperatures have been recorded at above the expected average for the Earth (NOAA, 2013).

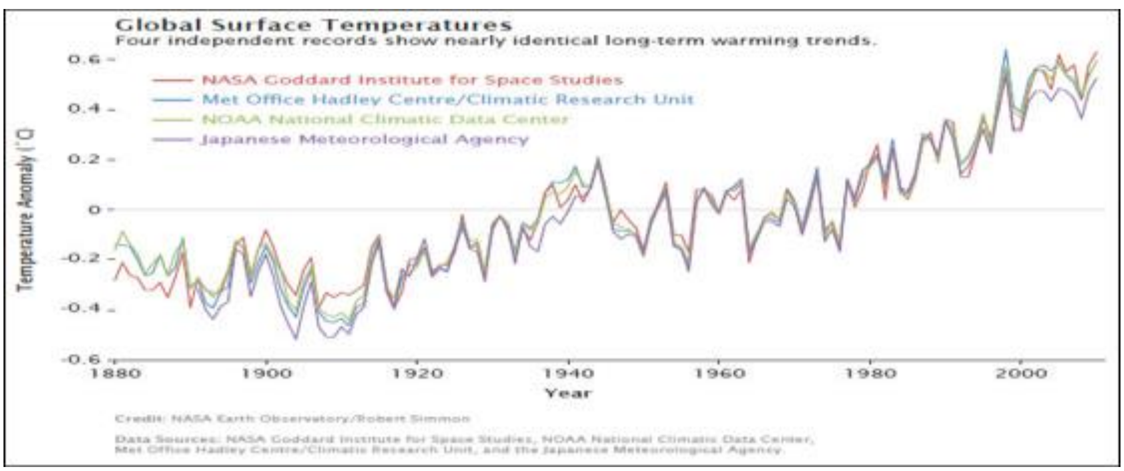

Figure 12. Global surface temperature vs. year. Graph from NASA website. (http://climate.nasa.gov/news/468): NASA Earth Observatory / Robert Simmon)

Global CO_2 level increase. Carbon dioxide (CO_2) is a greenhouse gas, which is given off by several human activities leading to humans directly causing about 80% of all global climate change (Flannery, 2005). There are several greenhouse gasses that contribute to global climate change, and CO_2 acts alone and also acts as an accelerator for other greenhouse gasses such as water vapor, methane, and nitrous oxide (Flannery, 2005). Carbon dioxide levels can be obtained for centuries back through ice core samples at the Arctic and Antarctic regions. These indicate a gradual increase in temperature. The reason scientists can tell the temperature of the Earth thousands of years ago is due to the knowledge of how greenhouse gasses work. It is known that the Earth's temperature will increase in a direct relationship with an increase in greenhouse gasses in the air. Also, when snow and ice are compacted, some of the air from that time period gets trapped in the ice. When the ice cores are melted in a controlled environment and measured, scientists can determine the concentration of greenhouse gasses in the air. For centuries past there has been an increase in CO_2, but in recent decades (1960s forward) there has been an exponential increase in CO_2 levels.

Carbon dioxide levels for the past century were around 290 parts per million in 1860 (Holechek et al., 2005), raising only to around 310 parts per million in 1960 (rate = 20 ppm / 100 years). After 1960, according to NASA (2013), the parts per million increased to 330 parts per million in 1980 (20 ppm / 20 years). From 1980 to 2000, according to NASA (2013), the parts per million increased to 360 parts per million (30 ppm / 20 years). There is clearly a significant rate change occurring in recent history (see Figure 13). This will inevitably lead to an increase in global temperature, which has been noted above. Because it is known that CO_2 levels correspond to Earth's temperature, this information can be used as a proxy measure for global climate change.

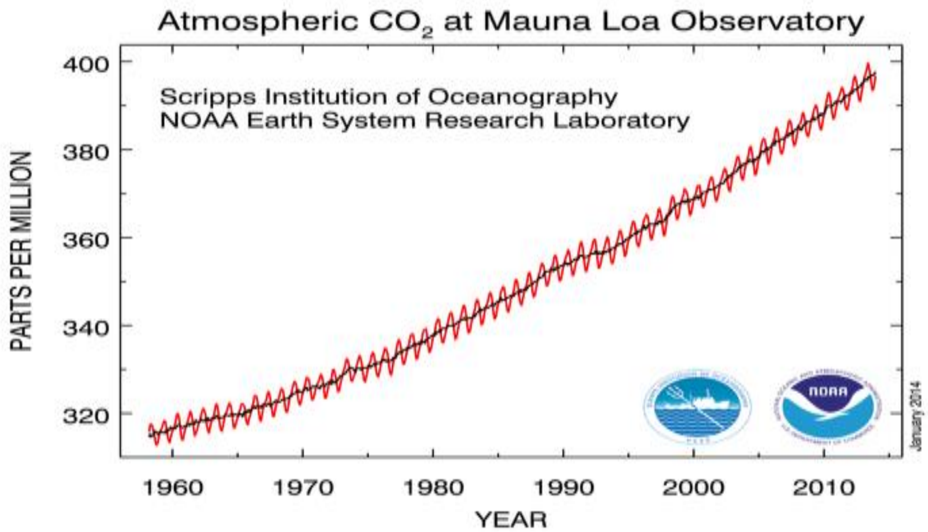

Figure 13. Atmospheric CO_2 vs. year. Graph from NASA website. (http://www.esrl.noaa.gov/gmd/ccgg/trends/): *Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/).*

Climate Change and Its Effects on Weather

The theory of climate change involves the fact that as carbon dioxide increases in the atmosphere, it will cause the Earth to heat up and grow warmer. This increase in temperature will have an effect globally including weather patterns changing, ocean tides changing, and seasons of drought and rain will be altered – not completely opposite, but in fact more severe in duration. An example of this can be seen in the increase in current flash floods due to dramatic increase in precipitation in short time periods followed by drought conditions and others. The change is from steady changes in weather patterns to sudden bursts of extreme weather. It is proposed by many, that these changes in climate change and weather patterns will have an effect on public health and infectious diseases.

Global climate change has affected many regions of the earth. There has been an increase in precipitation in the temperate zones and tropical zones around the world (Holechek et al., 2005). Corresponding to this, there has been a decrease in precipitation in the subtropical regions (Holechek et al., 2005). There has also been an increase of heavy precipitation events worldwide and increase in drought events and intensity in Africa and Asia (Holechek et al., 2005). There has also been an observed increase in cloud cover in medium to high latitudes and the average snow cover on the land has gone down about 10% since 1960 (Holechek et al., 2005).

Compared to 100 million years ago, the Earth is still in a cooler, interglacial event (Holochek et al., 2005). This means that Earth is not as hot as it was when the dinosaurs ruled the Earth, but Earth is not in a polar cold Earth either. The Earth's temperature has been warming for some time now, but what is new is the increase in the rate of the warming – the start of the rate increase coincides with the industrial revolution, and greatly increases around 1960, when owning a car and fossil fuel burning really began to increase (Holechek et al., 2005).

One unique factor that tends to affect the central Great Plains region, including Missouri, is the La Nina – El Nino cycle. This is a 22-year cycle that corresponds to polarity spots on the sun switching every 11 years (Holechek et al., 2005). This means typically there is 11 years of heavy rainfall, followed by 11 years of drought, and then the cycle repeats. Evidence for this can be seen in the droughts of the following decades: 1830s, 1850s, 1890s, 1910s, 1930s, 1950s, 1970s, 1990s, and currently in the 2010s (Holechek et al., 2005). This knowledge is critical in preventing further human caused climatic changes, such as the Dust Bowl that occurred in the 1930s. The Midwest of the country suffers droughts on a regular basis, so if too much of the land is changed from pasture land to farm land, when the drought strikes, it can cause climatic changes as far away as each coastline and affect the world grain production (Holechek et al., 2005).

One example of climate change affecting weather on a large scale is the observed shift in the South Pacific Convergence Zone (SPCZ), a giant rain band in the Southern Pacific (Cai, Lengaigne, Borlace, Collins, Cowan, McPhaden, et al., 2012). This rain band is greatly affected by Pacific Ocean temperature and tropical air circulation (Cai et al., 2012). The SPCZ also contributes to cyclone activity and whether the tropical island nations of the pacific will receive rain, floods, or droughts (Cai et al., 2012). With the increase in greenhouse gasses in the atmosphere, the direction, intensity, and range (North to South) of the SPCZ are being changed. This can and already has had drastic effects on the locations affected by the SPCZ. Some of the noted effects include, massive drought, food shortage, greatly increased coral bleaching, and an increase in cyclones near French Polynesia (Cai et al., 2012). Their predictive models show that the adverse weather events will only increase in frequency and magnitude over the upcoming century, and this irregularity in climate for the SPCZ will become the new norm.

In the Northern Hemisphere, the cyclone and wind activity are increasing in magnitude and frequency as well. A recent study demonstrates that with an increase in greenhouse gasses in the atmosphere, and temperature increase in the atmosphere and oceans, that weather patterns in the Northern Hemisphere concerning cyclones and extreme wind events are getting worse and happening more often (Champion, Hodges, Bengtsson, Keenlyside, & Esch, 2011). Within the past decade, there have been two flooding events in England, one major flooding event in Germany, and at least one major flooding event in the United States of America associated with cyclonic activity; and all of these have costs millions of dollars of damage (Champion et al., 2011). There has also been an increase in magnitude and frequency of wind events occurring in the winter in Europe that have costs millions of dollars of damage (Champion et al., 2011). They tested several models and have concluded that June, July, and August are the three months that are most significantly associated with an increase in cyclonic activity and wind activity (Champion et al., 2011). Weather events have become more severe and it should be expected that there would be more severe weather events on a more regular basis.

It is not just the warm weather storm events that are getting worse. In a recent new forum report, it is noted that in a joint effort the Intergovernmental Panel on Climate Change (IPCC) had two different groups (I- physicists and II- social impacts group) work together to determine what the realistic impact was not only on the weather, but on how that would affect human life. Their research showed that the global average temperature is getting warmer, and that means it is holding more water vapor in the air (Cooney, 2012). They also determined that the variation in weather was becoming more extreme, meaning that there are going to be more hot weather events and more cold weather events (Cooney, 2012). This sounds confusing, but because of global warming causing more water vapor to be held in the air, the winter weather storms (snow, ice, blizzards, etc.) have more water to work with and therefore they will be worse than in previous years. When the increase in global temperature and the increase in variability curves are put into one curve, it can be seen that the original curve is significantly different from the new curve which is shorter and broader, which means that climate has already changed (Cooney, 2012). Scientists predict further changes to come in the future as the Earth heats up and climate changes throughout the world.

Climate Change Affects Health

One of the first persons to hint at such a notion that weather might affect health was Alfred Haviland, a noted father of Health Sciences. He wrote several papers and books about what is now today called Epidemiology, but the one most critical to this research is titled, *Climate, Weather, and Disease* (1855). This may be one of the first scientifically supported published works on climate change affecting weather. In this book, Dr. Haviland demonstrates the differences between seasons in the cases of diarrhea, smallpox, and other diseases. He notes that temperature and precipitation are significant factors in the incidence of diseases in an age prior to modern epidemiologic and statistical techniques.

In more recent book, *Global Climate Change and Extreme Weather Events*, distributed by the Institute of Medicine of the National Academies (2008), climate change is again examined and examples are given of how climate affects human health. Examples given include Cholera, Rift Valley Fever, Plague, Drought, and various vector borne diseases. This book is a compilation of several research studies conducted throughout the world indicating that global climate change is affecting weather in various areas and having significant impacts on health.

Climate change will have an impact on overall health of society in general. There are several observable effects of climate change that can affect human health including increasing global temperature, worsening of the air pollution, altered airborne allergens, and increased and more severe extreme weather events (Cukic, 2012). One effect of global climate change is an increase in temperature. It is noted by Cukic (2012) that a 1 degree Celsius increase in temperature increases overall preventable mortality by up to 3% and respiratory mortality up to 6%. There are many studies that show an increase in air pollution, which acts as a respiratory irritant and can lead to increased rates of asthma and other respiratory disorders (Cukic, 2012). Sensitization to industrial pollutants is increased in industrialized cities compared to rural areas and this is also a contributory factor in increase in respiratory illness in a more polluted world. As temperatures are increasing, the growing range of several plants that are considered allergenic is spreading in range both North and South. There is also evidence that the allergenicity of these plants is increasing (Cukic, 2012). This increase and change in standard allergens of an area is increasing the response of the immune systems of many people and leading to increased cases of allergies, asthma, and other respiratory illnesses (Cukic, 2012). There is also evidence for more extreme weather events affecting the natural allergens in an area and magnifying their effect (Cukic, 2012). One example of this would be an increase in thunderstorms spreading more pollen dust, followed by a great increase in moisture in the air, which will help mold that was also stirred up by the wind to proliferate and grow in places it usually would not. It is known that several types of mold are allergenic and with a small amount of increase in moisture, they can survive on just about any surface. This increase in moisture in the air will increase the ability of these allergens to increase and increase respiratory illness in the general population (Cukic, 2012). Overall, there is evidence that global climate change is already affecting population health through several interactions, and it is only predicted to increase in magnitude as time goes forward.

These examples, along with the numerous examples mentioned in the background section demonstrate that weather has a significant effect on health; and that global climate change is affecting weather, which affects health. Overall, global climate change is affecting the weather of the entire world. Therefore, it is affecting the weather of Missouri. If it is known that temperature and precipitation are part of weather and weather affects health, then temperature and precipitation must be affecting health of Missouri residents. This study has demonstrated that temperature and precipitation are affecting the health of Missouri residents. This was done by reviewing the incidents of cases of giardiasis to determine if precipitation or temperature were affecting rates of incidence and if CO_2 was acting as a confounding, or significant variable in this study.

Summary

In this chapter I reviewed in depth the major factors involved in this research study. It has reviewed global climate change, including its history, causes, and effects. I have also explored the impacts on weather and health of global climate change. I further reviewed how global climate change might be affecting giardiasis in Missouri and what an outbreak of giardiasis might cost. In this chapter I also reviewed several cases, which were similar and which used similar measurement instruments, frameworks, and theories about weather affecting health. By now, I have allowed the reader to have an excellent understanding of Climate Change, giardiasis, and the background research which has led to the question of the possibility that precipitation and temperature may be affecting incidence rates of giardiasis in Missouri.

Chapter 3: Research Method

Introduction

This study was proposed to ascertain if the change in precipitation, temperature, or CO_2 levels in Missouri affected the number of cases of giardiasis of Missouri residents. Measurements of precipitation, temperature, and CO_2 levels were collected from reliable sources and compiled into one database. All data were analyzed statistically to determine if there was any interaction among precipitation, temperature, and CO_2 levels in Missouri affecting cases of giardiasis in Missouri residents.

Purpose of Study

The purpose of this research was to determine if weather and global climate change caused a significant change in number of cases of giardiasis in Missouri. The research involved collection of temperature and precipitation data, CO_2 level data, and data on cases of Missouri residents with confirmed giardiasis diagnosis. All these data were compared statistically to each other to determine if the precipitation, temperature, or CO_2 levels were affecting the health of Missouri residents concerning giardiasis. This was a cross-sectional design because the population of Missouri that was affected with giardiasis was compared to recorded temperature, precipitation and CO_2 levels to determine if there was a correlation. Knowing the location of the affected Missouri residents assisted in gaining more accurate temperature and precipitation data for those cases.

Study Design

Cross Sectional Designs

A cross-sectional study design was used to examine the associations of interest. Cross-sectional designs are not the gold standard in research, but they do allow researchers to study concepts and phenomenon that would otherwise be unable to study in an experimental design due to ethical or practical reasons (Checkoway, Pearcce, & Kriebel, 2004). In cross-sectional studies, many times data that is used was originally collected for some other purpose, such as a population survey or mandatory reportable disease reports (Crosby, DiClemente, & Salazar, 2006). This data can then be used for other study without the cost of data collection. It is not uncommon in cross-sectional studies for the data to have been collected for many decades and then applied some sort of predictive or preventive model. Data analysis controls can be put into place to improve research design and help with the clean comparison between groups (Frankfort-Nachmias & Nachmias, 2008).

Cross-sectional studies are usually one of the first means to attempt to gain evidentiary support for a hypothesis; then they are later followed by other more intense and specific studies (Crosby, DiClemente, & Salazar, 2006). One particular type of bias that cross-sectional studies tend to fall victim to is the ecologic fallacy (Checkoway, Pearce, & Kriebel, 2004). This is particularly true if the data they are using is collected at the individual level, and it is aggregated. This may give false results and will need to be accounted for in the statistical calculation and discussion (Crosby, DiClemente, &

Salazar, 2006). Many types of cross-sectional studies use individual level data that was previously collected for two variables, and then combine them into larger aggregate clumps (Checkoway, Pearce, & Kriebel, 2004). This is why cross-sectional designs are used as a starting place to gain evidentiary support for a hypothesis before much more time and money are spent on a study that may prove fruitless. If a significant correlation is found in a cross-sectional study, then it may warrant other types of studies, given that the original study did not fall victim to the ecologic fallacy (Frankfort-Nachmias & Nachmias, 2008). Cross-sectional studies are the least time consuming and least financially burdensome types of studies, which is why they are so common in scientific research.

Previous Studies Supporting the Study Design

This study was using the cross-sectional study design. Data for use in this study was previously collected for other purposes and was combined in a new way to determine if there was an association among factors that could lead to a predictive model. The data used in this study was collected on all variables during a set period. Although each variable could be tracked across time, that was not the purpose of this study. The purpose of cross-sectional studies is to see if one variable increases or decreases in a recognizable predictable way when influenced by another using collected data. This is a tool used in scientific research to help determine whether one factor is influenced by another, or even if one factor can predict another. In this study, number of cases of giardiasis were compared to precipitation, temperature, and CO_2 levels to determine if number of cases of giardiasis was influenced or predicted by precipitation, temperature, or CO_2 levels.

A similar cross-sectional study was conducted by Britton, Hales, Venugopal, and Baker (2010). In their study, the data were collected previously and they aggregated data of individual cases, precipitation, and temperature data, to the Census Area Unit (CAU) level. The data on individual cases came from notices sent out to the public from the National Notifiable Disease Surveillance System (NNDSS), and kept on record at the Environmental Science and Research Ltd (Britton et al., 2010, pp 563). The data on precipitation and temperature came from average climate station data in New Zealand (Britton et al., 2010, pp 563). The data from these sources were combined and statistics were performed to find significant positive associations among giardiasis and precipitation and temperature; as well as a positive relationship between cryptosporidiosis and precipitation, and a negative relationship between cryptosporidiosis and temperature (Britton et al., 2010, pp 567).

A cross-sectional design was used by Colon-Gonzalez, Fezzi, Lake, and Hunter (2013) in their study concerning weather and climate change on Dengue. The data used in this study was secondary collected from the Mexican National System of Epidemiologic Surveillance, the National Institute of Ecology, the National Institute of Statistics and Geography, and from the Mexican National Meteorological Service (Colon-Gonzalez et al., 2013). The defined time period was from 1985–2007 and the data were then aggregated by province (Colon-Gonzalez et al., 2013). The authors found that weather and Dengue are highly correlated, but the relationship is non-linear (Colon-Gonzalez et al., 2013).

Another cross-sectional study on Dengue was conducted in Australia to determine if weather variation and imported cases of Dengue were affecting naturally occurring rates of Dengue in Australia (Huang, Williams, Clements, & Hu, 2013). The study time frame was the years 2000–2009 and the aggregated individual measures into monthly averages or totals (Huang et al., 2013). They obtained their data from the Australian Bureau of Meteorology, Queensland Health, and Australian Bureau of Statistics (Huang et al., 2013). They performed statistics on the aggregate data and discovered that naturally occurring cases of Dengue were positively associated with imported cases of Dengue by month, low temperature of the month, and relative humidity of the month (Huang et al., 2013).

Enteric disease was studied using a cross-sectional design in New Zealand. This study examined the relationship of weather and climate variability on number of cases of enteric disease in New Zealand (Lal, Ikeda, French, Baker, & Hales, 2013). The data the researchers used was secondary data collected from the National Notifiable Disease Surveillance System, the Institute of Environmental Science and Research, and gridded surface temperature and precipitation time series records (Lal et al., 2013). These data were then aggregated into monthly measures and statistically analyzed. The time defined in the study was the years 1997–2008 (Lal et al., 2013). In this study, no factors were significantly related to giardiasis, temperature of previous month was positively associated with cryptosporidiosis, and temperature of current month was positively associated with Salmonellosis (Lal et al., 2013).

Mosquito population prediction by weather data were the subject of another cross-sectional study performed by Lebl, Brugger, and Rubel (2013). In this study the authors used variables of daytime length, temperature, precipitation, relative humidity, and wind speed as potential predictive factors for mosquito population size (Lebl et al., 2013). Daily measures were collected from the Desplaines Valley Mosquito Abatement District and from the weather station of the Chicago O'Hare International Airport for the assigned time period of years 1991–2010 (Lebl et al., 2013). These data were aggregated into weekly values and statistically analyzed to determine significance. Mosquito populations were significantly positively associated to daytime length 4-5 weeks prior to capture, temperature 2 weeks prior to capture; and significantly negatively associated with wind speed 3 weeks prior to capture (Lebl et al., 2013).

In Utah, a cross-sectional study was conducted concerning respiratory syncytial virus (RSV) and weather variables to determine if weather patterns can be used to help predict increase in case load of RSV (Walton, Poynton, Gesteland, Maloney, Staes, & Facelli, 2010). In this study the time frame of data collection was 1985–2008; and data were collected from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center, Salt Lake International Airport weather station, and the Intermountain Healthcare Enterprise Data Warehouse (Walton et al., 2010). Data were aggregated into outbreak seasons spanning from September 20th – July 15th of the following year and statistics were performed to determine significance of association among variables (Walton et al., 2010). Significant positive associations were found among RSV outbreaks and temperature and wind speed; although other factors were considered partially correlated in the final predictive model with a sensitivity of up to 67% and specificity up to 94% (Walton et al., 2010).

Diarrheal disease in Botswana was examined in a cross-sectional study using weather variables to determine predictability of disease from weather (Alexander, Carzolio, Goodin, & Vance, 2013). In this study the time frame examined was years 1974–2003; and data were extracted from the Climate Research Unit data set archived at the Royal Netherlands Meteorological Institute Climate Explorer Site, the Meteorology Department of the Botswana Government, and the Central Statistics Office at the Ministry of Health of the Botswana Government (Alexander et al., 2013). Individual measures were collected from secondary data and aggregated into monthly measures; then statistics were performed to determine significance (Alexander et al., 2013). Significant associations were found with precipitation, minimum temperature, and vapor pressure and cases of diarrheal disease in Botswana (Alexander et al., 2013). This lead to a predictive model, which indicates that the dry season is 20% worse for diarrheal disease than the wet season and will get worse based on this model (Alexander et al., 2013).

A final example of cross-sectional design being used in a similar study is the study of weather affecting the severe acute respiratory syndrome (SARS) outbreak in China (Bi, Wang, & Hiller, 2007). The time period for this study was 21 April to 20 May

2003 for Chinese cases and 17 March to 21 May 2003 for Hong Kong cases; and data were collected from the Hong Kong Government, the Ministry of Health of China, and the World Meteorological Organization (Bi et al., 2007). Individual cases and data were collected and aggregated into total daily values and data were statistically analyzed to determine significance (Bi et al., 2007). Results indicated an inverse correlation between minimum temperatures and relative humidity and SARS cases in Hong Kong; as well as a positive correlation among air pressure, relative humidity and SARS transmission (Bi et al., 2007). The study also found a negative association with minimum temperature and relative humidity on occurrence of SARS in Beijing, China (Bi et al., 2007).

It is clear from the aforementioned examples that cross-sectional design is very common in the public health field. Common factors of all of these studies included: a set time period, secondary data collection, aggregation of individual data into a larger clump of data, statistical analysis to determine significance of one factor on another, and most of the time a predictive model. All of these features were a part of this cross-sectional study as well.

Sampling

When conducting research, it is rarely possible to attain information from the entire population studied. In these cases, a technique called sampling is used. Depending on the research question, the sampling elements may be individual people or clusters (Crosby, DiClemente, & Salazar, 2006). When conducting epidemiologic studies, sampling involves collecting data on those affected with a disease of interest. In this study, data were collected from those infected with giardiasis in Missouri. Sampling involves taking a smaller subset of the population being studied that is representative of the population being studied (Frankfort-Nachmias & Nachmias, 2008). Epidemiologic investigations can rarely capture all persons with the disease due to lack of reporting or misdiagnosis. By attaining data from a representative sample, data can be extrapolated that data to the population being studied with some confidence if an adequate and truly representative sample was taken. In this epidemiologic investigation of waterborne disease in Missouri, data were extrapolated to the larger audience of Missouri residents that could in the future be affected by giardiasis in Missouri.

There are many important factors to consider when sampling, such as: identifying the exact target population, determining if the sampling be single or multistage, deciding on the selection process for individuals to be used in the sample, identifying whether stratification is necessary, determining selection process from list or not, and indicating the number of people in the sample and statistical procedures to determine this number (Creswell, 2009, pp 148). Researchers need to clearly define the target population, sample design, and sample size in order to have accurate results that are generalizable to the larger audience (Frankfort-Nachmias & Nachmias, 2008). Generalizability is a function of how well the sample represents the larger population (Crosby, DiClemente, & Salazar, 2006, pp 289).

Sampling Populations

Sampling strategy is important in any research study. The population must be clearly defined and the sampling frame must directly relate to the sampling population (Frankfort-Nachmias & Nachmias, 2008). Sampling frames are exhaustive lists of every person within a set population to be studied (Crosby et al., 2006). When conducting sampling research, it must consider whether the sampling frame exists and if it is accessible (Crosby et al., 2006). Errors in sampling can come in the form of incomplete frames, cluster of elements, and blank foreign elements (Frankfort-Nachmias & Nachmias, 2008). Choosing a large sample size, selecting individuals instead of clusters, can minimize these errors and using supplemental lists to compensate for missing data (Frankfort-Nachmias & Nachmias, 2008).

Population Studied

In this study, the target population was Missouri residents infected with waterborne diseases, specifically *Giardia* infections that can directly be traced back to water borne infection. In Missouri 2010, there were 426 cases of *Giardia* infections (Adams, Gallagher, Jajosky, Ward, Sharp, Anderson, Abellera, Aranas, Mayes, Wodajo, Onweh, & Park, 2012). Given the data collected from the 2010 reports, the estimated population for study accessible to the researcher was between 1,000–2,000 persons. The actual population sample size was around 5,000 cases. There are many cases of water borne disease that go unreported, and the reported cases surely made up only a small percentage of the total number of persons affected by waterborne disease. For consideration as a case in this study, the participants had to: 1) be a Missouri resident, 2) meet the case definitions set by the Centers for Disease Control and Prevention of giardiasis, and 3) had probable infection from a water source in Missouri. Case reports were used as the sample frame for this research in order to collect vital statistical data from infected persons from 2003—2013 as were available from the Missouri Department of Health and Senior Services.

Missouri Population

Missouri covers 68,741.52 square miles of land with 811 square miles of water (U.S. Census Bureau [USCB], 2010). It is located in the middle of America and experiences all four seasons of weather. Missouri is primarily rural with only a few urban centers. Missouri has 8 border-states including: Arkansas, Illinois, Iowa, Kansas, Kentucky, Nebraska, Oklahoma and Tennessee. Missouri is known as the tributary state and has thousands of tributaries (creeks, streams, and smaller rivers) that run toward several rivers in the state of Missouri including the Missouri River and the Mississippi River. Missouri's tributaries run into it from surrounding states and drain out of it to other surrounding states. Missouri's economy primarily depends on agriculture (cattle, soybeans, hogs, dairy products, corn, poultry and eggs) and industry (transportation equipment, food processing, chemical products, electrical equipment, and fabricated metal products) according to the USCB (2010). Because Missouri is centrally located in the United States and near so many other states, the weather in Missouri and microbial load in the water could have an effect on other states surrounding it. Methods of this study could be repeated and results applied to other states surrounding Missouri to assist in determining the impact of weather on human health.

The human population in Missouri is 6,010,688 (USCB, 2010). Missouri has approximately 23.5% of the population below18 years of age, and 14.2% of the population is over 65 years of age (USCB, 2010). The sex distribution of the population is female 51%, male 49% (USCB, 2010). Race distribution in Missouri is as follows: 84% white, 11.7% Black, and 4.3% other races (USCB, 2010). In Missouri, 86.2% of the population graduated from high school, 25% of the population has a Bachelor's degree or higher (USCB, 2010). The median household income is 46,262 annually, and approximately 14% of the population lives below the poverty line (USCB, 2010). Most of Missouri residents live in medically underserved areas (MDHSS, 2012). Overall, the use of the public waterways in Missouri by residents increases dramatically during the summer. In the past, Missouri has experienced an increase of waterborne disease morbidity and mortality during the summer months. Missouri residents have many ways to access public waterways and it is important to continue monitoring these waterways for the health and safety of Missouri residents and the residents of other states. It is also important to continue monitoring for waterborne diseases, like giardiasis, to assist in raising awareness of the potential threats to health and safety of Missouri residents and the residents of surrounding states.

Sampling Style Used in this Study

This was a Non-probability sampling research study. The population of Missouri residents actually infected with water borne diseases was unknown due to underreporting, misdiagnosis, and not seeking health care attention concerning water borne disease illnesses. Because the actual population of Missouri residents infected each year with water borne illness was unknown, this could not be a probability sampling study. The sample of Missouri residents with water borne illnesses was taken from case reports of Missouri residents reported during the study time frame. This type of sampling is known as convenience sample, because the researcher takes whatever sample they can easily attain and analyze data concerning that sample. The sample frame to work from is incomplete, so all reported cases were used. The unreported cases of water borne illness are thought to be much higher than the reported cases, so the sample taken was representative of the larger population of Missouri residents infected with water borne illness. This was an early stage research study, and provided valuable knowledge for future, more refined studies.

Sample Size

When performing scientific research using a sample, it is critical that the sample size be large enough to accurately represent the population studied. In order to have valid results, a sample usually must be at least 5% of the population or 2000 people (Frankfort-Nachmias & Nachmias, 2008). Selection of sample size can be determined by knowing what level of accuracy is expected (standard error) in the study (Frankfort-Nachmias &

Nachmias, 2008). When choosing a sampling size, two statistics test to consider are standard error and confidence interval. These two factors, in consideration with the actual population size and budget should be considered for determining sample size. Sample size can affect the effect size in a given study, so sufficient measures should be taken to ensure a proper sample size to gain accurate effect size determinations (Crosby et al., 2006). Three statistical values that are critical in statistically determining sample size include: Statistical power, Alpha, and Effect size (Burkholder, n.d.). The accepted value for statistical power is 0.80 or 80% chance of correctly predicting outcomes (Burkholder, n.d.). The accepted standard Alpha level is 0.05, also referred to as the 95% confidence interval. Effect size can be determined by the *t*-statistic, and R^2 (square of coefficients, multiple regression) and W^2 values (measure of effect size for ANOVAs), according to Burkholder (n.d.).

In this study, it was assumed that the sample of all reported cases was at least 5% of all cases that include reported and unreported cases of water borne illness of giardiasis in Missouri residents. The expected number of reported cases in the sample was between 1,000 and 2,000 cases; but the actual number of reported cases was about 5,000 cases. All the water borne diseases are reportable diseases to the CDC, so all reported cases had case records that were included in the study. Excluded were the cases that did not meet the case definition as described earlier in this study. It is thought that up to 50% of cases of water borne illness go unreported in Missouri (MDHSS, 2012). An expected sample size of 1000 cases was used, and it was assumed that 50% of cases go unreported; the sample size would be approximately 50% of the population studied. Using the 95% confidence level, the population estimate at 2000 and the sample size of 1000, calculated confidence interval expected for the study was +/- 2.19%. Using the 95% confidence interval, estimated population of 2000, and confidence interval of 2.19, the sample size needed was 1001 reported cases. (Creative Research Systems Sample Size Calculator was used to assist in confirming calculated expected confidence interval and sample size needed.) Using population size of 2000, sample size of 1000, 50% sample proportion, and 95% confidence interval, the Sample Error was calculated to be 2.2%. (Decision Support Systems Calculators was used to assist in confirming calculated expected sample error.) Statistical power and Effect size were calculated after data were gathered.

Instrumentation

Scale/Index for Measurement Instrument

The data collected and analyzed in this research study dealt with the physical data associated with health. Measures taken were from the hard sciences of physics and chemistry, as well as reported numbers of cases of giardiasis in Missouri residents. They were not subject to change based on individual human factors. Scale measures were inappropriate for this research study. These measures were part of an index, which attempted to gain an understanding of how weather affects human health. In this study the variables of precipitation, temperature, CO_2 levels, and number of cases of giardiasis in Missouri residents were compared to each other to determine if one has any effect on the others. This type of measurement has been used in several other studies and has proven to be a valid and reliable tool for using weather patterns to predict epidemiologic factors that affect human health. This test (index) was norm based, because weather patterns, and morbidity and mortality rates can be normalized and used to determine variation from the normal patterns expected.

In order to understand how weather affects human health, a wide area was chosen to study. The state of Missouri is a wide range and supports a great deal of variations in weather. Precipitation can only be accurately measured in reference to weather patterns over large areas, and the same is true for temperature and CO_2 levels. The entire state of Missouri provided a wide enough range for appropriate sampling of precipitation and temperature and CO_2 levels that could be affected by that precipitation, temperature, and CO_2 levels. Finally, because incidence and prevalence of waterborne morbidity and mortality are relatively low in the United States of America, it requires a large sample area to accumulate sufficient numbers for statistical tests. In order to acquire those numbers, the large area of the state of Missouri was used which corresponds to the aforementioned variables of precipitation, temperature, CO_2 levels and number of cases of giardiasis of Missouri residents. By gathering data throughout the state of Missouri on all four variables, it was desired to gain a better understanding of how weather and global climate change affects human health.

Levels of Measurement

In this study, measurements were taken of precipitation, temperature, CO_2 levels and number of cases of giardiasis. All of the data collected was measured using the ratio level of measurement, which is the highest level of measurement (Frankfort-Nachmias & Nachmias, 2008). In ratio level of measurement, variables have absolute and fixed zero points and the ratio between any two numbers is independent of the unit of measurement, for example, temperature (Frankfort-Nachmias & Nachmias, 2008). The four levels of relations attained by this form of measurement are: equivalence, greater than, known distance of any two intervals, and true zero points (Frankfort-Nachmias & Nachmias, 2008). This data can be transformed to any of the other three forms of data measurement, including nominal, ordinal, and interval, because it is the highest level of measurement (Frankfort-Nachmias & Nachmias, 2008). Precipitation and temperature data were collected through reports compiled by the National Climatic Data Center (NCDC) on each day for each county in Missouri from 2002—2014, which included the desired sample time frame of 2003—2013. Carbon dioxide levels data were acquired from the Environmental Protection Agency (EPA) reports of CO_2 level emissions by state for the desired time frame. Information on cases of Missouri residents with giardiasis was collected from the Missouri Department of Health and Senior Services (MDHSS).

Reliability

When a measurement is taken, it is important for the instrument of that measure to be reliable. Reliability is determined when a test instrument gives consistent results between trials and over time (Crosby, DiClemente, & Salazar, 2006). This can be done using a standardized instrument that is universally accepted (like a thermometer for temperature), or create a new measurement tool and perform various tests to determine if it is reliable (Creswell, 2009). By using a tested, reliable instrument for collecting data, the researcher can avoid bias and have a more valid research study. Reliability can be established for tests and scales by using the test-retest method (Crosby et al., 206).

The measurements taken in this study were taken from tested reliable instruments that have been used for years to collect these forms of data. Precipitation and temperature data is monitored closely by the National Climatic Data Center, and was used in this report. This data has been tested and retested and has been used for many published data reports, and is highly reliable. The Environmental Protection Agency (EPA) in Missouri collects the CO2 emissions levels in Missouri, and the data they use for CO_2 emissions reports was used in this report (EPA, 2012). Collection of data concerning cases of Missouri residents with giardiasis came through the reports of the local public health departments in Missouri. The Missouri Department of Health and Senior Services (MDHSS) maintains records of morbidity and mortality in databases that are updated regularly (MDHSS, 2012). A complete dataset was requested from the Missouri Department of Health and Senior Services that contained all pertinent information about cases of Missouri residents with giardiasis. This measuring instrument has been used for many years and is reliable and valid (MDHSS, 2012). All instruments of measure used were standardized and have been used in research and data analysis for many years (EPA, 2012; MDHSS, 2012).

All of these measurements were taken and used as an index of weather and global climate change affecting health concerning giardiasis cases of Missouri residents. This type of index has been used several times in previous publications using measurements of precipitation, temperature, CO_2 levels, and number of cases of waterborne disease. This gave the index and measures face validity, because other experts have already agreed that it was reliable and valid (Curriero et al., 2001; Lebl et al., 2013; White et al., 2009; Shaman et al., 2002; and Kolivras & Comrie, 2004). Content validity could have been improved with the addition of other measures. There are other measures that could be taken to widen the index, but for this report, four measures sufficed to answer the questions posed (Crosby, DiClemente, Salazar, 2006).

Validity

Measurement instruments must be reliable and valid in order for the research to be considered valid. In order for a measurement tool to be considered valid, it should demonstrate the ability to measure what it is supposed to measure (Crosby, DiClemente, & Salazar, 2006). There are three main types of measurement validity: content, empirical, and construct validity (Frankfort-Nachmias & Nachmias, 2008).

Content validity is concerned with covering all aspects of the variable being measured (Frankfort-Nachmias & Nachmias, 2008). The measurement tool that was used in this research covered the aspects of interest for this particular research study. It could be expanded for a more accurate picture of how weather affects health in the future. The measurement tool had face validity because it measured what it is designed to measure. Sampling validity is concerned with determining whether the population under study is adequately sampled by the measuring instrument (Frankfort-Nachmias & Nachmias, 2008). Because every county in Missouri was used and standardized sampling techniques used by the state for many years (such as how temperature was recorded in tenths of degrees Celsius and precipitation was recorded in tenths of millimeters across the state) were used, this research study had high sampling validity. All precipitation and temperature measures for each county, CO_2 levels from the state, and all reported cases of Missouri residents with giardiasis were used in the analysis of data.

Empirical validity is concerned with whether the instrument used in the research did measure accurately the variables it was trying to measure as compared with some sort of standard measure of the variable (Frankfort-Nachmias & Nachmias, 2008). If the instrument used in the research does not correlate positively with the standard instrumentation, there will be low empirical validity and the research may be viewed skeptically. The instruments used in this research are the standard instruments used by the National Climatic Data Center throughout the United States of America, including recording temperature in tenths of degrees Celsius, and precipitation in tenths of millimeters. The Environmental Protection Agency uses the reported CO_2 output of all businesses reporting for all states in the United States as a standardized measurement reported by year. The MDHSS is responsible for reporting every known case of giardiasis to the CDC because giardiasis is a reportable disease to the CDC, so it can be assumed that their records are a reliable and valid source of data. Because the instrument used in this research was the standard instrument of measure in all cases, it had high empirical validity.

Construct validity ties back to the theory chosen to support the research hypotheses; and, determines if the theoretical framework of the study is logically and empirically connected to the instrumentation used in the study (Frankfort-Nachmias & Nachmias, 2008). For this threat to instrument measurement bias to be avoided, the researcher has to demonstrate the ability to recognize and measure the variable in question with their instrumentation (Frankfort-Nachmias & Nachmias, 2008). The theory of global climate change was the theory used in this research. Changes in weather patterns and their effects on the environment and life are key components of this theory. By measuring precipitation, temperature, CO_2 levels, and mortality and morbidity due to waterborne disease, supported claims can be made about the effect of precipitation, temperature and global climate change on human health. This measurement tool ties back to the theory and can be used to further support the premise of the theory, therefore it has construct validity.

Previous Studies Supporting the Measurement Instrument

There have been several studies using the same or similar measuring instruments and index to determine the effect of weather on human health. In these studies, one or more measure of weather, one or more measure of global climate change, and one or more measure of human health were included in an index of weather affecting health. Many of these indexes collected data from other sources that have high reliability and validity, which increased validity and reliability in the study.

One such study included weather patterns and case counts for pneumococcal disease (White, Ng, Spain, Johnson, Kinlin, & Fisman, 2009). The researchers in this study identified associations between weather patterns and pneumococcal disease through use of an index (White et al, 2009). The index used included: measures of cases of pneumococcal disease, temperature, wind speed, relative humidity, atmospheric pressure, and rain fall (White et al., 2009). Their environmental data were collected from a weather station and their case counts were collected from local public health departments (White et al., 2009). Their data were analyzed using Poisson regression models, meta-analytic Q-statistics and meta-regression models (White et al., 2009).

Drought and the effect it had on mosquito populations was the focus of a study by Chase and Knight (2003). In this study, there was an association found between drought and mosquito outbreaks in wetland areas (Chase & Knight, 2003). Their index for measurement included: mosquito larvae, soil permanence as a determination of water in the soil, precipitation levels, and competitors of the mosquitoes (Chase & Knight, 2003). All data in this research was collected by the researchers and analyzed using statistical methods including: ANOVA and Tukey’s HSD.

Cryptosporidiosis and giardiasis were analyzed in another study concerning changing weather patterns (Britton, Hales, Venugopal, & Baker, 2010). Cryptosporidiosis and giardiasis are waterborne diseases that are affected by climate change according to the researchers (Britton et al., 2010). Their index for measuring the impact of climate change on human health included: precipitation, temperature, quality of domestic water supplies, urban-rural status, deprivation, and notification of cryptosporidiosis and giardiasis in humans (Britton et al., 2010). Their data were collected from the Census Area Unit from previous years' data (Britton et al., 2010). The research was supported statistically through the use of confidence intervals, negative regression, multivariate analysis, and various rates and ratios (Britton et al., 2010).

Precipitation rate and water-borne outbreaks in human populations in the United States was the focus of the research conducted by Curriero, Patz, Rose, and Subhash (2001). The researchers in this study analyzed data from 40 years-worth of data and found that about half of waterborne disease outbreaks occurred after a heavy precipitation event (Curriero et al., 2001). This also means that about half occurred when there was not a heavy precipitation event (Curriero et al., 2001). The index used in this study included: EPA reported water-borne disease outbreaks and precipitation data from the National Climatic Data Center (Curriero et al., 2001). Statistical tests performed were chi-square tests and a MonteCarlo version of the Fisher exact tests (Curriero et al., 2001).

Another study examined the possibility that humidity levels affect Legionellosis in the human population (Fisman, Lim, Wellenius, Johnson, Britz, Gaskins, Maher, Mittleman, Spain, Haas, & Newbern, 2005). The researchers in this study found a high association between humidity and Legionellosis in the Philadelphia area (Fisman et al., 2005). The index used in this study included: reported cases of Legionellosis and humidity data (Fisman et al., 2005). Reported cases were collected from the public health departments and local airport weather stations and weather stations in Montgomery county weather station (Fisman et al., 2005). Statistical tests used were Poisson regression analysis and a case-crossover study approach.

Saint Louis Encephalitis (SLE) and drought were researched and suspected of being associated in another study using the concept that climate can affect human health (Shaman, Day, & Stieglitz, 2002). The researchers in this study found that drought actually facilitated the transmission of SLE and increase in human infection rates (Shaman et al., 2002). The index in this study included: sentinel chicken infection, mosquito numbers, and meteorological data including precipitation and humidity (Shaman et al., 2002). Data were collected from the National Climate Data Center and from the Indian River Mosquito Control District Archives (Shaman et al., 2002). Statistical support for the conclusion was in the form of univariate and bivariate logistic regression and Wald's chi-square test (Shaman et al., 2002).

Weather patterns were thought to be a possible predictor of and vector borne illness of West Nile Virus infection in a study conducted by Wang, Minnis, Belant, and Wax (2010). The researchers found a positive association with dry weather and outbreaks of West Nile Virus (WNV) infections in humans (Wang et al., 2010). The index used in this case included: case reports of WNV in humans and precipitation rates (Wang et al, 2010). The data were collected from the Mississippi State Health Department and county level weather stations in Mississippi (Wang et al., 2010). Statistics that supported this conclusion were standard morbidity ratio, Bayesian hierarchal models, and conditional auto-correlative models (Wang et al., 2010).

Data Analysis Plan

This study included five research questions that required two main types of analysis. The first three research questions, which addressed the potential effects of precipitation, temperature, and CO_2 on number of cases of giardiasis in Missouri residents, used bivariate linear regression. This allowed it to be determined if potential predictor variable had a significant correlation with the criterion variable of number of cases of Missouri residents with giardiasis. The fourth and fifth research questions were asked to assess effect modification and required a model that includes an interaction term. A multivariate linear regression was used to assess these research questions. SPSS was used to analyze data.

Descriptive Statistics

Descriptive statistics allow researchers to manage data and present it in an understandable manner (Green & Salkind, 2011). Frequency distributions allow researchers to understand the patterns presented by the collected data (Frankfort-Nachmias & Nachmias, 2008). Measures of central tendency allow researchers to find the average of the group studied and describe the distributions of data collected (Frankfort-Nachmias & Nachmias, 2008). Measures of Central tendency include: mode, median, and mean. There are several measures of dispersion that can identify the range of responses, minimum and maximum variable numbers, and standard deviation from the expected mean or normal distribution (Frankfort-Nachmias & Nachmias, 2008). Using descriptive statistics, researchers can gain a better understanding of the population studied and how this population may vary from the normal distribution of the population. The statistical assumptions of the test were that it was normally distributed and there were enough variables entered to accurately calculate frequency distribution (Green & Salkind, 2011). Descriptive statistics compared demographic census data gathered (age, race, gender, and county of origin – rural or urban) of the affected population with that of the general population of Missouri.

Intent and Variables

The intention of this study was to determine if precipitation, temperature, or CO_2 were associated with the number of cases of giardiasis in the human populations in Missouri. Comparisons were made of the previous years based on precipitation, temperature, CO_2 levels and human cases of giardiasis in Missouri. Comparisons were made of the confirmed cases and the temperature and precipitation one week and two weeks prior to confirmation of the case of giardiasis. The reason for this, as aforementioned in Chapter 1, is that there are two different isolates of giardiasis (*Giardiasis duodenum* isolate A and B) that can infect humans and the symptomatic stage of giardiasis can range from one to two weeks or more after infection, if the person became symptomatic at all. If measurements were taken of only one week prior to infection, the results may not reflect accurately the weather patterns actually affecting the infection and transmission association with weather (temperature and precipitation) that favor or discourage the transmission of giardiasis from environment to host. By having tested for one week and two weeks prior to infection, it can be said with confidence that the weather patterns one week or two weeks do or do not significantly affect the infection rates of the host. From this study, it was hoped that some sort of predictable pattern would emerge among precipitation, temperature, and CO_2, and number of cases of giardiasis of Missouri residents and that this data could be used in the future to lower and prevent human morbidity and mortality due to waterborne illness in Missouri residents. The independent variables were precipitation, temperature and CO_2 levels in Missouri. The dependent variable was number of cases of giardiasis in Missouri residents.

Table 1

Hypothesis, Variables, Statistical Tests, and Covariates.

Hypothesis	IV	DV	Statistical Tests	Covariates
Research Hypothesis 1: There is an association between precipitation and number of cases of giardiasis in Missouri residents.	Precipitation in area of Missouri one week prior and two weeks prior to confirmed case status (precipitation in inches)	Giardiasis status yes (number of giardiasis cases by month)	Bivariate analysis using linear regression: 1) precipitation 1 week prior compared to giardiasis cases, 2) precipitation 2 weeks prior compared to giardiasis cases	age, race, gender, county
Research Hypothesis 2: There is an association between temperature and number of cases of giardiasis in Missouri residents.	Temperature in area of Missouri one week prior and two weeks prior to confirmed case status (temperature in degrees F)	Giardiasis status yes (number of giardiasis cases by month)	Bivariate analysis using linear regression: 1) temperature by 1 week prior to compared to giardiasis cases, 2) temperature by 2 weeks prior compared to giardiasis cases	age, race, gender, county
Research Hypothesis 3: There is an association between CO_2 and number of cases of giardiasis in Missouri residents.	CO_2 levels in Missouri by lowest time variable (currently year)	Giardiasis status yes (number of giardiasis cases by month)	Bivariate analysis using linear regression: compare giardiasis cases by month to average CO_2 emissions	age, race, gender, county
Research Hypothesis 4: The association between precipitation and giardiasis among Missouri residents is modified by CO_2 levels.	Precipitation in area of Missouri one week prior and two weeks prior to confirmed case status (precipitation in inches), CO_2 levels in Missouri by lowest time variable (currently year)	Giardiasis status yes (number of giardiasis cases by month)	Multivariate analysis of 2 independent variables to predict dependent variable	age, race, gender, county
Research Hypothesis 5: The association between temperature and giardiasis among Missouri residents is modified by CO_2 levels.	Temperature in area of Missouri one week prior and two weeks prior to confirmed case status (temperature in degrees F), CO_2 levels in Missouri by lowest time variable (currently year)	Giardiasis status yes (number of giardiasis cases by month)	Multivariate analysis of 2 independent variables to predict dependent variable	age, race, gender, county

Research Questions

Research Question 1

Is there an association between precipitation and the number of cases of giardiasis in residents of Missouri?

$H_0$1: There is no association between precipitation and the number of cases of giardiasis in residents of Missouri.

H_a1: There is an association between precipitation and the number of cases of giardiasis in residents of Missouri.

Statistical Tests Explanation: Each case had data collected on the dependent predictor variable (precipitation 1 week prior and 2 weeks prior) and the independent criterion variable (giardiasis status). The cases were grouped by month so each month had a certain number of cases and an average precipitation (averaged from specific precipitation data for each case during the month). There were two bivariate analysis using linear regression: one with average precipitation 1 week prior compared to number of cases of giardiasis, and one with average precipitation 2 weeks prior compared to number of cases of giardiasis. This demonstrated whether precipitation 1 week or 2 weeks prior to confirmed case status was a statistically significant predictor variable for number of cases of giardiasis. The R^2 number showed how significant the association between the predictor variable (precipitation) and the criterion variable (giardiasis status) was, and what percent of the criterion variable (number of cases of giardiasis in Missouri residents) was predicted by the predictor variable (average precipitation). Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban. If any statistically significant associations existed between average precipitation and giardiasis, an analysis of confounders and covariates was checked to determine if they were significant. Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban.

Research Question 2

Is there an association between temperature and the number of cases of giardiasis in Missouri residents?

$H_0$1: There is no association between temperature and the number of cases of giardiasis in Missouri residents.

H_a1: There is an association between temperature and the number of cases of giardiasis in Missouri residents.

Statistical Tests Explanation: Each case had data collected on the dependent predictor variable (temperature 1 week prior and 2 weeks prior) and the independent criterion variable (giardiasis status). The cases were grouped by month so each month had a certain number of cases and an average temperature (averaged from specific temperature data for each case during the month). There were two bivariate analysis using linear regression: one with average temperature 1 week prior compared to number of cases of giardiasis, and one with average temperature 2 weeks prior compared to number of cases of giardiasis. This demonstrated whether temperature 1 week or 2 weeks prior to confirmed case status was a statistically significant predictor variable for number of cases of giardiasis. The R^2 number showed how significant the association between the predictor variable (temperature) and the criterion variable was, and what percent of the criterion variable (number of cases of giardiasis in Missouri residents) was predicted by the predictor variable (average temperature). Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban. If statistically significant associations exist between average temperature and giardiasis, an analysis of confounders and covariates was checked to determine if they were significant. Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban.

Research Question 3

Is there an association between CO_2 and the number of cases of giardiasis among residents of Missouri?

$H_0 1$: There is no association between CO_2 and the number of cases of giardiasis among residents of Missouri.

$H_a 1$: There is an association between CO_2 and the number of cases of giardiasis among residents of Missouri.

Statistical Tests Explanation: Each case had data collected on the dependent predictor variable (CO_2 emissions in Missouri, currently by year, so each case in that year had the same number) and the independent criterion variable (giardiasis status). The cases were grouped by month so each month had a certain number of cases and an average CO_2 level (year CO_2 level divided by 12 months). One bivariate test, using linear regression, was run comparing the number of cases per month to the average CO_2 emissions by month. The R^2 number showed how significant the association between the predictor variable (CO_2 level) and the criterion variable was, and what percent of the criterion variable (number of cases of giardiasis in Missouri residents) was predicted by the predictor variable. If statistically significant associations exist between CO_2 levels and giardiasis, an analysis of confounders and covariates was checked to determine if they were significant. Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban.

Research Question 4

Is the association between precipitation and giardiasis modified by CO_2 levels?

$H_0$1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between precipitation and giardiasis among Missouri residents is modified by CO_2 levels.

Statistical Tests Explanation: This part of the study took the variables for precipitation and CO_2 and paired them together two at a time in order to determine if there were any significant associations using two predictor variables. This was done using a multivariate analysis comparing the following:

- Precipitation one week prior and monthly CO_2 levels to cases of giardiasis,
- Precipitation two weeks prior and monthly CO_2 levels to cases of giardiasis.

Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban. The multivariate analysis determined if CO_2 was affecting the relationship between precipitation and giardiasis in Missouri residents. Only models with significance at least at the $p < 0.05$ level were considered significant. This question relates directly to the theory of global climate change.

Research Question 5

Is the association between temperature and giardiasis modified by CO_2 levels?

$H_0$1: The association between temperature and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between temperature and giardiasis among Missouri residents is modified by CO_2 levels.

Statistical Tests Explanation: This part of the study took the variables for temperature and CO_2 and paired them together two at a time to determine if there were any significant associations using two predictor variables. This was done using a multivariate analysis comparing the following:

- Temperature one week prior and monthly CO_2 levels to cases of giardiasis,
- Temperature two weeks prior and monthly CO_2 levels to cases of giardiasis.

Possible confounding variables (covariates) included: age, race, gender, and county of origin – rural or urban. The multivariate analysis determined if CO_2 was affecting the relationship between temperature and giardiasis in Missouri residents. Only models with significance at least at the $p < 0.05$ level were considered significant. This question relates directly to the theory of global climate change.

Limitations

This research had some limitations that needed to be addressed. There were factors that were beyond the control of the researcher due to the nature of the cross-sectional research. Some limitations of cross-sectional research included the use of secondary data, and the inability to gather further data from original sources. Other concerns arose when considering validity and reliability issues which included the combination of different instrumental measures for data collection. Sample size was limited to that which was officially reported and recorded as a case according to the CDC definition, so any misdiagnosed or unconfirmed cases were not included. This study intentionally limited the number of factors as it was an initial study and that may have skewed the results. If more factors were considered, then perhaps a more accurate model could have been made, but the purpose of this study was an initial study, so limiting factors was important.

Potential Effects on Research

There were several potential effects on the research due to factors outside the control of the researcher. Covariates were factors that could affect the nature of the populations being studied. Public awareness campaigns or closing of waterways sooner or later than previous years could affect the relationship between the variables. Also, if precipitation changed from expected patterns that could also have affected waterborne disease populations in unexpected ways. Also, any unanticipated pollution or chemical contamination of waterways might have affected microbial concentration in unknown ways. Effect modifiers are factors that influence the population to behave in a certain way. The ability to access the waterways or preference for water parks might be a cultural modifier that affected the infection rates of various parts of the population from natural waterway contamination.

Avoidance of Ecologic Fallacy is critical in scientific research. Because these results were taken from Missouri and applied specifically to Missouri, there was little chance of ecologic fallacy. Precipitation and temperature data were matched up to each individual case by county because of the great variation in temperature and precipitation experienced by different regions of Missouri. This was done to ensure accurate temperature and precipitation data to each case. The CO_2 levels were taken at the state level and were applied the same to all areas of the state despite geographic variation. This was due to the availability of data only at the state level, and not the county level. Further analysis may be conducted later to determine if there were higher rates in certain areas, but that is another research project (Kennedy, 2012).

Avoidance of Individualistic Fallacy is also critical in scientific research. Because HIPAA protects most private health information, there were no conclusions drawn about the persons who became infected concerning socio-economic status. Sex, race, age, place and date of infection were pertinent information as well as infecting organism. The only conclusions drawn were concerning the change in temperature, precipitation, and CO_2 levels and the numbers of infected individuals broken down by sex, age, race, and infectious organism. The results came from the whole state and no personal characteristics were attached to the research and anonymity was respected. The only use for data concerning race, sex, age, etc. was to determine if the population being affected was significantly different than the population of Missouri as a whole, or if one group was more affected than the others. Results were gathered through reports from local and state public health agencies (Frankfort-Nachmias & Nachmias, 2008).

Methodological Considerations

The measuring instruments used have several strengths and limitations. Some of the strengths of the measuring instruments included: high reliability, good content validity, high empirical validity, and high construct validity. These instruments of measure have been used time and time again for official reports and serve as the standard of measurement for what they are designed to measure. One limitation of this type of measuring tool was that it depended on secondary data collected by others who may have been trained differently or at different times. Finally, there was always the threat of information and data entered or transcribed incorrectly due to human error. That was why it was important for a second person to confirm the data reported by the first for this study. This may have led to fluctuations in reliability in the instruments.

Sampling Potential Errors or Bias

There are many types of errors that could be introduced when performing sample research. Non-response error occurs when potential participants do not respond to the requests asked by the survey or sampling (Frankfort-Nachmias & Nachmias, 2008). Sampling bias might be introduced when other factors not attributed to chance alone interfere with sample results (Crosby et al., 2006). Design effect could influence the validity of cluster sampling due to multistage process sampling (Crosby et al., 2006). Snowball sampling introduces a large amount of bias in selection both by the researcher and the participants (Crosby et al., 2006). It is important to remember that the results of the study cannot be generalized beyond the target population for which they were sampled (Crosby et al., 2006).

In this study, it was assumed that approximately 50% of the population being studied did not have their illness reported. That left 50% of those affected in the sample population. Because all data were collected from case reports, potential errors from non-participation in the sample were minimal. All case reports (100% of known cases) were included in the study, which minimizes mortality in the study. Bias might have been introduced when records were taken or by interviewer bias. The instrument of sampling was standardized and set forth by the CDC, so instrument bias was minimized. Sampling bias might have occurred because those that came to seek medical attention when affected by water borne illness might have been fundamentally different than those who do not. By using convenience sampling, bias associated with snowball sampling and cluster-sampling techniques were avoided. The results of this study were applied to the target population and could be applied to future generations of the target population. Lessons learned from this research might be applied to general public health practices in Missouri to help prevent future water borne illnesses in Missouri.

Ethical Concerns

This study did have some ethical considerations that needed to be addressed. The use of an IRB committee was used to determine any ethical considerations that were not addressed directly within this document. The data that was collected in the study came from several different sources, and their contributing party gave consent for the data to be used if it was not in the public domain. Precipitation and temperature data to be collected was in the public domain. Data to be collected concerning Missouri residents with giardiasis was attained with permission of the Missouri Department of Health and Senior Services (MDHSS). There were no personal interviews conducted by the researcher, nor was any personal data of such a nature necessary for this investigation. Only basic descriptive factors were obtained from the records attained and disease (giardiasis) and origin of disease. All records attained for use during the study will be destroyed after the required time to keep the data is met. The data included in this study was intended for application in the state of Missouri only and may be different in other states, so comparisons should be made warily. The IRB approval number for this study is 07-31-15-0224451.

Summary

In conclusion, the data for this research study was gathered from the Missouri Department of Health and Senior Services, the National Climatic Data Center, and the Environmental Protection Agency websites. These data were all collected second hand and was analyzed using SPSS. This type of research was validated by many other similar studies and will add to the body of knowledge on how weather affects human health and how global climate change may be affecting that relationship. Chapter 4 examines the actual numbers gathered on Missouri residents concerning all variables established above. These are statistically analyzed and presented for review in Chapter 4.

Chapter 4: Results

The purpose of this quantitative research was to determine whether temperature, precipitation and CO_2 levels are associated with giardiasis cases in Missouri. The research questions and hypotheses of the study were as follows:

Research Question 1

Is there an association between precipitation and the number of cases of giardiasis in residents of Missouri?

$H_0$1: There is no association between precipitation and the number of cases of giardiasis in residents of Missouri.

H_a1: There is an association between precipitation and the number of cases of giardiasis in residents of Missouri.

Research Question 2

Is there an association between temperature and the number of cases of giardiasis in Missouri residents?

$H_0$1: There is no association between temperature and the number of cases of giardiasis in Missouri residents.

H_a1: There is an association between temperature and the number of cases of giardiasis in Missouri residents.

Research Question 3

Is there an association between CO_2 and the number of cases of giardiasis among residents of Missouri?

$H_0$1: There is no association between CO_2 and the number of cases of giardiasis among residents of Missouri.

H_a1: There is an association between CO_2 and the number of cases of giardiasis among residents of Missouri.

Research Question 4

Is the association between precipitation and giardiasis modified by CO_2 levels?

$H_0$1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

Research Question 5

Is the association between temperature and giardiasis modified by CO_2 levels?

$H_0$1: The association between temperature and giardiasis among Missouri residents is not modified by CO_2 levels.

*H*a1: The association between temperature and giardiasis among Missouri residents is modified by CO_2 levels.

This chapter includes information on the data collection and analysis and the results of the study are presented here. Within this chapter there is a descriptive analysis of the variables, a description of the population studied, and the results of the bivariate and multivariate analyses (including linear regressions). The findings are reported in this chapter using appropriate probability values and confidence intervals. The findings of the linear regression models are included as well as any predictive formulas provided by the statistical program. The findings of the study are presented at the end of the chapter.

Data Collection

After obtaining IRB Exemption (see Appendix A) from the Missouri Department of Health and Senior Services (MDHSS), IRB approval was granted from Walden University (number 07-31-15-0224451). Then data on every recorded case of giardiasis in Missouri between 2002–2013 was obtained to include information on age, race, ethnicity, gender, diagnosis date, and county of origin from MDHSS. Every case met CDC diagnosis criteria at the time of diagnosis. Data collection and compilation occurred between June 2014 and December 2015.

Temperature and precipitation data were acquired online through a request to the National Climatic Data Center (NCDS) because they had more accurate weather data records broken down by county in Missouri so it could correlate to the cases individual locations where infections occurred. These data were acquired in August 2015 to ensure the most accurate and up to date information on all possible locations and data in Missouri. Temperature and precipitation data were collected for every county in Missouri for 2002–2014 and included high and low temperatures in tenths of degrees Celsius and precipitation and snowfall accumulations in millimeters.

Finally, the Environmental Protection Agency (EPA) provided a summary of carbon dioxide (CO_2) levels in the air for Missouri covering the period from 2001–2013. The most up to date information for this was obtained in December 2015, which included the year 2013, which was not on the previous data sets sent. This data included CO_2 emissions from fossil fuel combustion in millions of metric tons CO_2 per year.

After all data were acquired, data were input into an Excel Spreadsheet where all three data sets were combined. Each case had a listed county of origin, which had to be matched to the temperature and precipitation data for that county at the time of diagnosis. When each of 5014 cases had the data for temperature and precipitation average one week and two weeks prior entered, and CO_2 data were entered for each case, then the data were imported into IMB SPSS Statistical Program version 23. The data were then coded for analysis. The task of combining the data sets and writing programs to calculate averages for each case for temperature and precipitation occurred between August 2015 and November 2016.

There were many variables used in this analysis, which include county, precipitation, temperature, sex, age, race, ethnicity, and date of diagnosis. In the combined data set, each case was given a unique identifier (a number) and the county of origin was kept as a text variable. Rain and snow variables for 1 week prior (Rain1WK and Snow1WK) and 2 weeks prior (Rain2WK and Snow2WK) were averaged out for each case to give the average precipitation variables for 1 week (AvgPrecip1WK) and average precipitation variables for 2 weeks (AvgPrecip2WK) prior to date of diagnosis. Temperature maximum and minimum variables for 1 week prior (Tmax1WK and Tmin1WK) and for 2 weeks prior (Tmax2WK and Tmax2WK) were also averaged out for each case to give the temperature average variables for 1 week prior (TAVG1WK) and 2 weeks prior (TAVG2WK) to date of diagnosis. The CO_2 variable was given in years, so divided evenly by 12 to give an average CO_2 by month variable for each year (CO_2byMonth). The date of diagnosis variable was entered as a calendar date including two spaces for month/ two spaces for day/ and two spaces for year, for example 01/01/03 (DateDiagnosed). From the date, a secondary variable was introduced (MonthofInfection) to classify each case by month of infection from the first month of the first year (January 2003) to the last month of the last year (December 2013) and were numbered from 1 – 132 accordingly. Each case was also given another variable (Month) to assign a number (1 -12) to each month of the year to a number for further analysis (e.g. January = 1, February = 2, etc.).

Using the month of infection variable (MonthofInfection), the cases per month variable was calculated (CasesperMonth) and grouped each case into one of the months of the study from 1–132. Then the monthly average precipitation variables for one week prior to date of diagnosis (WK1Precip) and for two weeks prior to diagnosis (WK2Precip) were calculated averaging the Average precipitation variables for 1 week prior to diagnosis (AVGPrecip1WK) and two weeks prior to diagnosis (AVGPrecip2Wk) for all cases in the given month of infection (MonthofInfection). Then the monthly average temperature variables for one week prior to date of diagnosis (WK1Temp) and for two weeks prior to date of diagnosis (WK2Temp) were calculated averaging the average temperature variables for 1 week prior to diagnosis (TAVG1WK) and for 2 weeks prior to diagnosis (TAVG2WK) for all cases in the given month of infection (MonthofInfection).

The sex variable was left as a text variable of Male or Female (Sex); and the Age variable was given in total years as a whole number (Age). Race and Ethnicity variables were left as text variables (Race and Ethnicity). These were used in descriptive statistics to help understand the population studied and compare it to the standard Missouri population.

Statistical Analysis of the research questions included variables of temperature, precipitation, and CO_2. The statistical analysis used the averaged variables for temperature for 1 week prior to diagnosis (WK1Temp) and 2 weeks prior to diagnosis (WK2Temp), precipitation for 1 week prior to diagnosis (WK1Precip) and 2 weeks prior to diagnosis (WK2Precip), and CO_2 by month variable (CO_2byMonth). These were classified by cases per month variable (CasesperMonth) and by month of infection during the time of the study from 1–132 (MonthofInfection).

Population of Sample of Giardiasis Cases Collected in MO 2003-2013

The sample collected included a total of 5,014 cases of reported giardiasis in Missouri from 2003–2013; with 4,977 cases having data reported completely, and 37 cases missing some data. When broken down by month of occurrence during the year, the months of July, August, September, and October, have at least 100 more cases than the other months of the year, which is a significant increase from the rest of the year (see Table 2). The histogram curve is skewed slightly to the right again demonstrating the most likely months of infection between July and October (see Figure 14).

There were 2,322 females (46.3 %) and 2,662 males (53.1 %) in this sample. The most affected race in this sample was White (49.4%); and the most affected ethnicity was Non-Hispanic with 53% (see Table 3). Most of the case diagnoses were confirmed by Diagnosis (43.9%), Onset of Disease (28.3%), or Test at 26.7% (see Table 4). Ages of persons in the study ranged from 0–94 years, with a disproportionate amount of cases occurring before the age of 10 (see Figure 15).

Table 2

Missouri Cases of Giardiasis by Month 2002–2013

	Month	Frequency	Percent	Valid Percent
Valid Cases	1	327	6.5	6.6
	2	312	6.2	6.3
	3	332	6.6	6.7
	4	336	6.7	6.8
	5	314	6.3	6.3
	6	371	7.4	7.5
	7	584	11.6	11.7
	8	623	12.4	12.5
	9	554	11.0	11.1
	10	523	10.4	10.5
	11	351	7.0	7.1
	12	350	7.0	7.0
	Total	4,977	99.3	100.0
Missing	System	37	0.7	
Total		5,014	100.0	

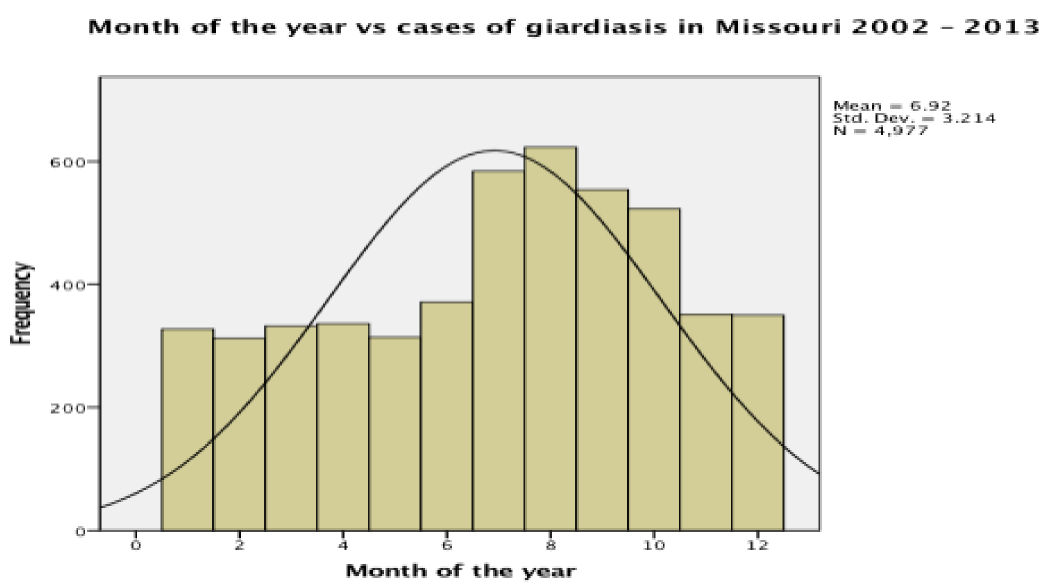

Figure 14. Month of the year vs. cases of giardiasis in Missouri 2002–2013.

Table 3

Race and Ethnicity of Giardiasis Cases in Missouri 2002–2013

Race	Frequency	Percent
Asian	229	4.6
Black	576	11.5
Indian	7	0.1
Multiple race	14	0.3
Other race	5	0.1
Pacific Islander	5	0.1
Unknown race	1,701	33.9
White	2,477	49.4
Total	5,014	100.0
Ethnicity		
Hispanic	144	2.9
Non-Hispanic	2,658	53
Unknown Ethnicity	2,212	44.1
Total	5,014	100.0

Table 4

Diagnosis Types for Giardiasis Cases in Missouri 2002–2013

Diagnosis	Frequency	Percent	Valid Percent
Missing data	17	0.3	0.3
Diagnosis	2,201	43.9	43.9
Onset	1,417	28.3	28.3
Received	23	0.5	0.5
Report	15	0.3	0.3
Test	1,341	26.7	26.7
Total	5,014	100.0	100.0

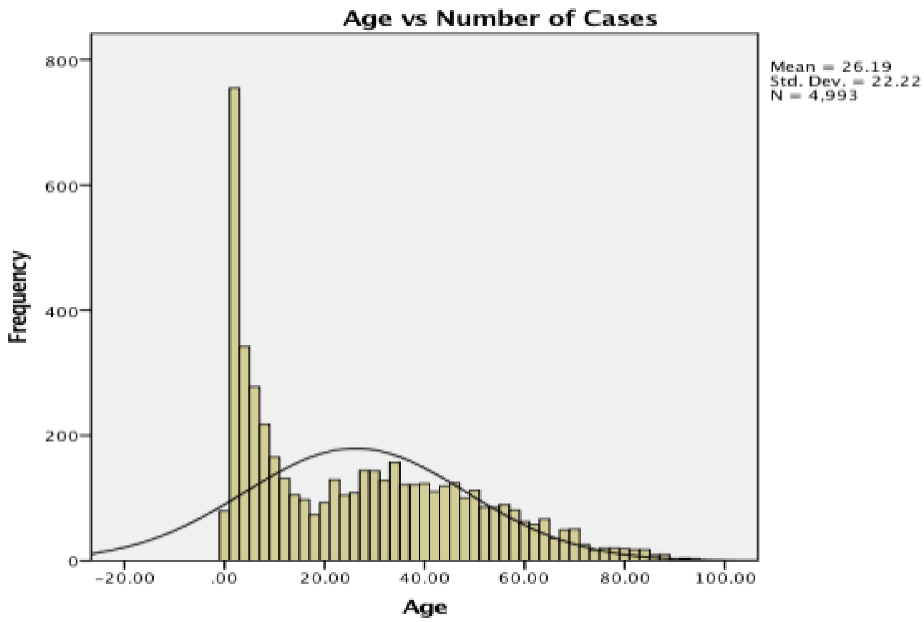

Figure 15. Age of cases of giardiasis in Missouri.

Representative Sample

This sample is not representative of the population in Missouri, but is a representative sample of those in Missouri affected by giardiasis. This sample was collected from all the available cases of reported giardiasis in Missouri between the designated years. A total of 5,014 cases were collected which gives this study significant statistical power justifying the effect size reported in the data. Every available case was used, but they are random because no one intentionally went and infected people with giardiasis to collect data in this study, and nature selected these persons to be infected. In this sample the male to female ratio is approximately 50:50 within an acceptable range of variance. The race distribution in the sample differs slightly from the race distribution in Missouri, and that may be partially due to a lack of reporting of race on the collected data. If the unknown cases reported were added to the White category of race, then the sample would match up very well. It cannot be assumed that the unknown races are all White, so this is a point of difference between the stated population of Missouri and the recorded data sample (see Table 5). There is an age difference in this sample and the population of Missouri. The population of Missouri has approximately 23.5 % of the population less than 18 years of age (USCB, 2010) and the collected sample has 44.90 % of the sample population under the age of 18 years. Also, the population of Missouri has 14.2 % of the population above age of 65 years (USCB, 2010), and the collected sample has 5.49 % of the sample population over the age of 65 years. The population of Missouri also has 62.3% of population between the ages of 18 and 65 (USCB, 2010); and the collected sample has 49.61 % of the sample population between the ages of 18 and 65 years. This is an indication that there is some difference in the population sample and the general population of Missouri, but is representative of who is most affected by the disease. As aforementioned, the very young and elderly are most affected by giardiasis and it makes sense that they would have higher numbers in the sample than compared to the standard Missouri population.

Table 5

Race Distribution in Missouri by Percent 2002–2013

	Census Missouri Population [a]	Giardiasis Sample Population
White	84.0	49.4
Black	11.7	11.5
Other	4.3	5.2
Unknown	0.0	33.9

a. United States Census Bureau, 2010

Covariate Non-Inclusion Justification

Potential covariates of Sex, Race, Ethnicity, Population Density (Rural vs. Urban), and Age were considered for this analysis. Each variable was counted and entered into SPSS by variable cases per month. Variable classifications for Sex, Race, and Ethnicity were made by the Missouri Department of Health and Senior Services (MDHSS) as follows: Sex was classified as Male or Female; Race was classified as White, Black or Unknown; and Ethnicity was classified as Hispanic, Non-Hispanic, and Unknown. Variable Classification for Rural or Urban status was made using the Missouri 2010 Population and Housing Counts (see Appendix B) produced by the 2010 Census of Population and Housing (U.S. Department of Commerce, 2012). Counties were classified as rural or urban based on the Census Bureau data and entered as such into SPSS for counts per month of rural cases or urban cases. Finally, Age variable was classified by every 10 years by this researcher and entered for cases per month counts into SPSS. After all this was done, analysis could be run for each new potential covariate separately to determine if they affected the R^2 or significance of the variables proposed in the hypotheses aforementioned.

A linear regression was run for each potential covariate cases per month against precipitation, temperature, CO_2 per month, and the combined variables of CO_2 and precipitation and CO_2 and temperature. There was no significant change in the R^2 value for any potential covariate tested. For the following covariates, all variables showed no significance at the $p = .01$ level: Race Black, Ethnicity Hispanic, Age 61-70, and Age 70 and above. The potential covariate of Ethnicity Hispanic showed significance of temperature only at $p = .025$ level, and all other variables remained insignificant. These analyses have determined that according to this data, the potential covariates of Race Black, Ethnicity Hispanic, Age 61-70, and Age 70 and above are not significantly affected by the variables of precipitation, temperature, and CO_2. For these covariates, other variables should be examined in the future. Covariates were not included in the model because no increase in significance of any potential covariate was observed on any variable tested.

All data were gathered as described in Chapter 3 and in the above section. The data gathering took longer than anticipated, but all data were gathered and analyzed as previously described. No adverse events occurred due to this data gathering and analysis.

Results

The results of the study are below in this section and include descriptive statistics of the variables for precipitation, temperature, CO_2, and cases per month. The linear regression analyses are also included for each research question considered.

Descriptive Analyses

Between 2003–2013, there were a total of 5,014 cases with 4,977 cases being valid and including all needed data for analysis. These were broken down into monthly totals (132 months). There was an average of approximately 38 cases per month, with a maximum of 82 cases per month (see Table 6). The cases per month varied on a yearly cycle with peaks and valleys that corresponded to high and low temperatures. The range between peak (highest number of cases per year) and valley (lowest number of cases per year) decreased over time, showing a decrease overall in number of cases as time passed (See Figure 16). The variables of precipitation were measured for 1 week prior and 2 weeks prior to diagnosis. There was no significant difference between these two variables (see Table 6). The variables of temperature were measured for 1 week prior and 2 weeks prior to diagnosis. There was also no significant difference between these two variables (see Table 6). Figure 16 shows the monthly variance of temperature 1week prior to diagnosis including peaks and valleys that correlate to the weather seasons in Missouri (See Figure 16). Figure 16 shows the direct relationship between temperature and cases of giardiasis in Missouri. As temperature increased, cases of giardiasis increased; and as temperature decreased, cases of giardiasis decreased. The carbon dioxide variable has remained fairly consistent over the time of this study with slight dips in the years 2010 and 2012. Carbon dioxide was measured in millions of metric tons, and was found to have a significant impact on the other variables.

Table 6

Descriptive Statistics Weather and Environmental Variables

Statistic	Cases per Month	Precip 1 Week Prior [a]	Precip 2 Weeks Prior [a]	Temp 1 Week Prior [b]	Temp2 Weeks Prior [b]	CO_2 by Month [c]
N Valid	130	132	132	132	132	132
Missing	0	0	0	0	0	0
Mean	37.7	4.1	4.0	129.9	130.2	113.6
Median	34.0	3.5	3.6	132.1	134.9	114.2
Mode	32.0	0.6	0.6	-39.6	-35.5	105.9
St. dev.	15.9	2.5	2.3	99.2	92.00	3.8
Variance	252.3	6.4	5.2	8506.3	8462.9	14.3
Range	79.0	14.0	13.1	335.1	328.9	12.8
Minimum	3.0	0.6	0.6	-39.6	-35.5	105.9
Maximum	82.0	14.6	13.8	295.5	293.4	118.7

[a] Precipitation reported in millimeters
[b] Temperature reported in tenths of degrees C
[c] CO_2 reported in millions of metric tons.

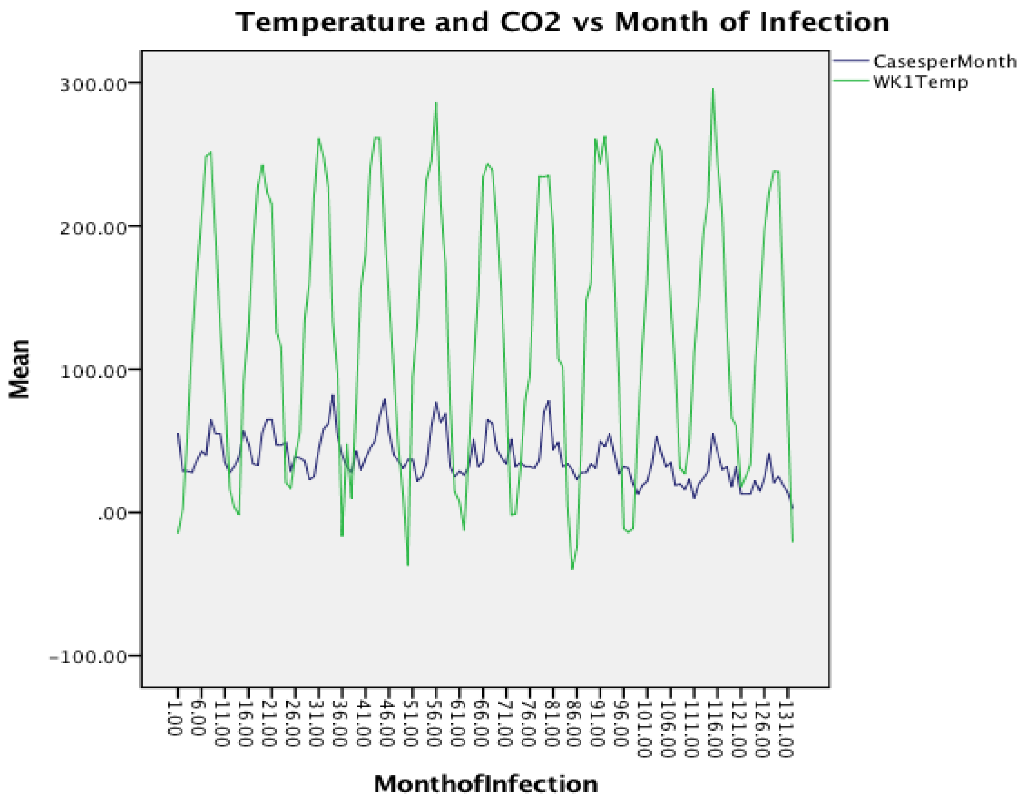

Figure 16. Month of infection vs. cases per month and temperature.

Assumptions of Statistical Tests Met

In this research, bivariate and multivariate tests were used. Bivariate and multivariate linear regressions were used because the research needed to test continuous variables against another continuous variable to determine if one was impacting the other, and/or modified by a third continuous variable. Random-effects models were used in this research because the cases were chosen randomly by nature. The subjects were not intentionally infected, but were randomly selected by nature to acquire this disease. The first assumption of the Random-effects model for bivariate linear regression is that "the two variables are bivariately normally distributed in the population" (Green & Salkind, 2011, pp. 277). The variables tested included precipitation 1 week prior to diagnosis, precipitation 2 weeks prior to diagnosis, temperature 1 week prior to diagnosis, temperature 2 weeks prior to diagnosis, and carbon dioxide vs. cases per month of giardiasis. After running tests for normality in SPSS, all the variables tested were normally bivariately distributed according to the Shapiro-Wilk Test for normality for all cases at all levels above 0.05, excluding outliers. Outliers were excluded in the data analysis to ensure validity of the test. The second assumption of the Random-effects model for bivariate linear regression is that "the cases represent a random sample from the population, and the scores on each variable are independent of the other scores and the same variables" (Green & Salkind, 2011, pp. 277). These cases were random samples and each case is independent of all other cases on all variables tested.

The assumptions for the multivariate linear regression Random-effects model are similar to the bivariate linear regression. The first assumption of the multivariate linear regression Random-effects model is that "the variables are multivariately normally distributed in the population" (Green & Salkind, 2011, pp. 288). After running tests for normality in SPSS, all the variables tested were normally multivariately distributed according to the Shapiro-Wilk Test for normality for all cases at all levels above 0.05, excluding outliers. Outliers were excluded in the data analysis to ensure validity of the test. The variables tested included precipitation 1 week prior to diagnosis and carbon dioxide, precipitation 2 weeks prior to diagnosis and carbon dioxide, temperature 1 week prior to diagnosis and carbon dioxide, and temperature 2 weeks prior to diagnosis and carbon dioxide vs. Cases per month of giardiasis. The second assumption of the multivariate linear regression Random-effects model is that "the cases represent a random sample from the population, and the scores on variables are independent of other scores on the same variables" (Green & Salkind, 2011, pp288). These cases were random samples and each case is independent of all other cases on all variables tested. The variables tested included precipitation 1 week prior to diagnosis, precipitation 2 weeks prior to diagnosis, temperature 1 week prior to diagnosis, temperature 2 weeks prior to diagnosis, and carbon dioxide vs. cases per month. Using these results, the assumptions of the statistical tests were met for all bivariate and multivariate linear regression tests run in this research.

Linear Regression and Moderator Variable Analysis

An interaction or moderator term was examined using statistics. The variables of precipitation 1 week prior to diagnosis, precipitation 2 weeks prior to diagnosis, temperature 1 week prior to diagnosis, temperature 2 weeks prior to diagnosis, and monthly CO_2 were standardized into new variables. Then a moderator variable was made for each case in research questions 4 and 5: Moderatorp1 = precipitation 1 week prior standardized variable x monthly CO_2 standardized variable; Moderatorp2 = precipitation 2 weeks prior standardized variable x monthly CO_2 standardized variable; ModeratorT1 = temperature 1 week prior standardized variable x monthly CO_2 standardized variable; ModeratorT2 = temperature 2 weeks prior standardized variable x monthly CO_2

standardized variable. The linear regression test was run once with the moderator variable and once without the moderator variable for each case. The two models for each case were compared. In all cases, the moderator variables were insignificant in the linear regression and made the model statistically weaker (R^2 values lower), so the moderator variables were excluded from the final models in this research.

Research Question 1

Is there an association between precipitation and the number of cases of giardiasis in residents of Missouri?

$H_0$1: There is no association between precipitation and the number of cases of giardiasis in residents of Missouri.

H_a1: There is an association between precipitation and the number of cases of giardiasis in residents of Missouri.

Precipitation 1 week prior to diagnosis. A linear regression analysis was conducted to evaluate the relationship between precipitation 1 week prior to diagnosis with giardiasis and number of cases per month of giardiasis in Missouri between 2003–2013. The scatterplot for the two variables (see Figure 17) indicates that the two variables are linearly related such that as overall precipitation 1 week prior to diagnosis increases, cases of giardiasis in Missouri decrease. The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = 44.92 - 1.76(\text{Week 1 precipitation})$$

The 95% confidence interval for the slope [-2.81, – 0.71] does not contain the value of zero, and therefore precipitation 1 week prior to diagnosis is significantly related to the cases per month. Precipitation 1 week prior to diagnosis has a small impact on number of cases of giardiasis per month. Accuracy in predicting cases per month of giardiasis was weak. The correlation between precipitation 1 week prior to diagnosis and cases of giardiasis per month was -.280. Approximately 8% of the variance in cases per month of giardiasis was accounted for by the linear relationship with the precipitation 1 week prior values (see Table 7). The results of the ANOVA test are significant, $F(1,130) = 4.84$, $p = .01$. The p value is less than .05, so the null hypotheses that there are no differences between groups was rejected (see Table 7). Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0.

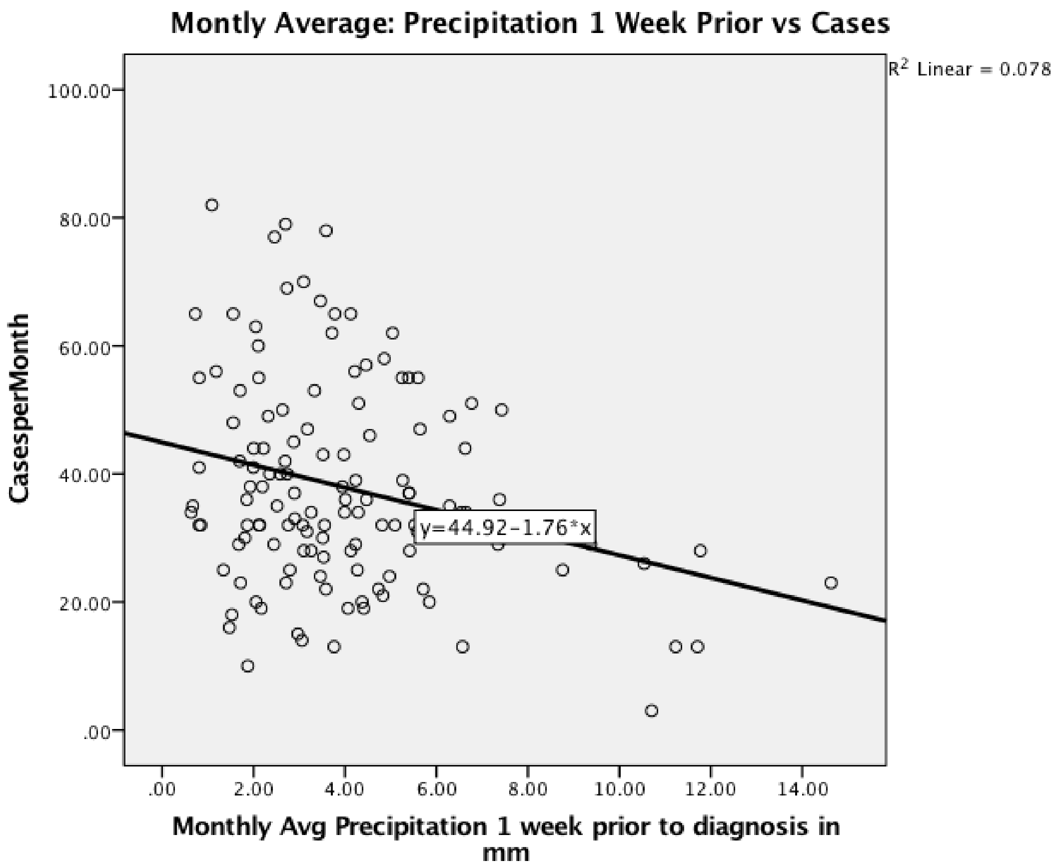

Figure 17. Week 1 precipitation vs. cases giardiasis per month Missouri.

Table 7

Regression Analysis Results for Individual Variables

Individual Models	Constant	B	95%CI	F(1,130)	Zero Order	P	R^2
Precip1WK	44.92	-1.76	[-2.81, -0.71]	11.04	-.280	.001	.078
Precip2WK	44.62	-1.71	[-2.89, -0.54]	8.30	-.245	.005	.060
Temp1WK	27.24	0.08	[0.05, 0.11]	36.63	.469	<.001	.220
Temp2WK	26.93	0.08	[0.06, 0.11]	38.96	.480	<.001	.231
CO_2	-134.14	1.51	[0.83, 2.19]	19.31	.360	<.001	.129

Note. Dependent Variable: CasesperMonth.

Precipitation 2 weeks prior to diagnosis. A linear regression analysis was conducted to evaluate the relationship between precipitation 2 weeks prior to diagnosis of giardiasis and number of cases per month of giardiasis in Missouri between 2003–2013. The scatterplot for the two variables (see Figure 18) indicates that the two variables are linearly related such that as overall precipitation 2 weeks prior to diagnosis increases, cases of giardiasis in Missouri decrease. The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = 44.62 – 1.71(\text{Week 2 precipitation})$$

The 95% confidence interval for the slope [-2.89 to – 0.54] does not contain the value of zero, and therefore precipitation 2 weeks prior to diagnosis is significantly related to the cases per month. Precipitation 2 weeks prior to diagnosis has a small impact on number of cases of giardiasis per month. Accuracy in predicting cases per month of giardiasis in Missouri was weak. The correlation between precipitation 2 weeks prior to diagnosis and cases of giardiasis per month was -.245. Approximately 6% of the variance in cases per month was accounted for by the linear relationship with the precipitation 2 weeks prior values. The results of the ANOVA test are significant, $F(1,130) = 8.30$, $p = .005$. The p value is less than .05, so the null hypothesis that there are no differences between groups was rejected (see Table 7). Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0.

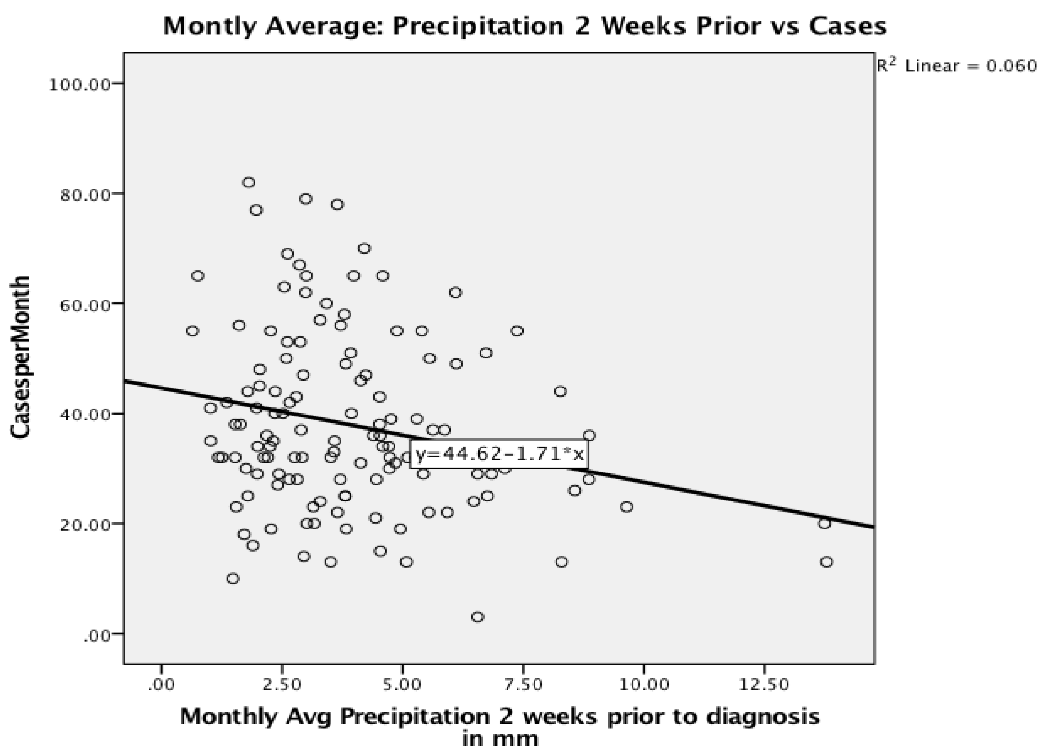

Figure 18. Week 2 precipitation vs. cases per month giardiasis in Missouri.

Research Question 2

Is there an association between temperature and the number of cases of giardiasis in Missouri residents?

$H_0$1: There is no association between temperature and the number of cases of giardiasis in Missouri residents.

H_a1: There is an association between temperature and the number of cases of giardiasis in Missouri residents.

Temperature 1 week prior to diagnosis. A linear regression analysis was conducted to evaluate the relationship between temperature 1 week prior to diagnosis with giardiasis and number of cases per month of giardiasis in Missouri between 2003–2013. The scatterplot for the two variables (see Figure 19) indicates that the two variables are linearly related such that as overall temperature 1 week prior to diagnosis increases, cases of giardiasis in Missouri increases. The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = 27.24 + 0.08(\text{Week 1 temperature})$$

The 95% confidence interval for the slope [0.05, 0.11] does not contain the value of zero, and therefore temperature 1 week prior to diagnosis is significantly related to the cases per month. Temperature 1 week prior to being diagnosed has a small impact on number of cases of giardiasis per month. Accuracy in predicting cases per month of giardiasis in Missouri was weak. The correlation between temperature 1 week prior to diagnosis and cases of giardiasis per month was .469. Approximately 22% of the variance in cases per month of giardiasis was accounted for by the linear relationship with the temperature 1 week prior to diagnosis values. The results of the ANOVA test are significant, $F(1,130) = 36.63$, $p < .001$. The p value is less than .05, so the null hypothesis that there are no differences between groups was rejected (see Table 7). Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0.

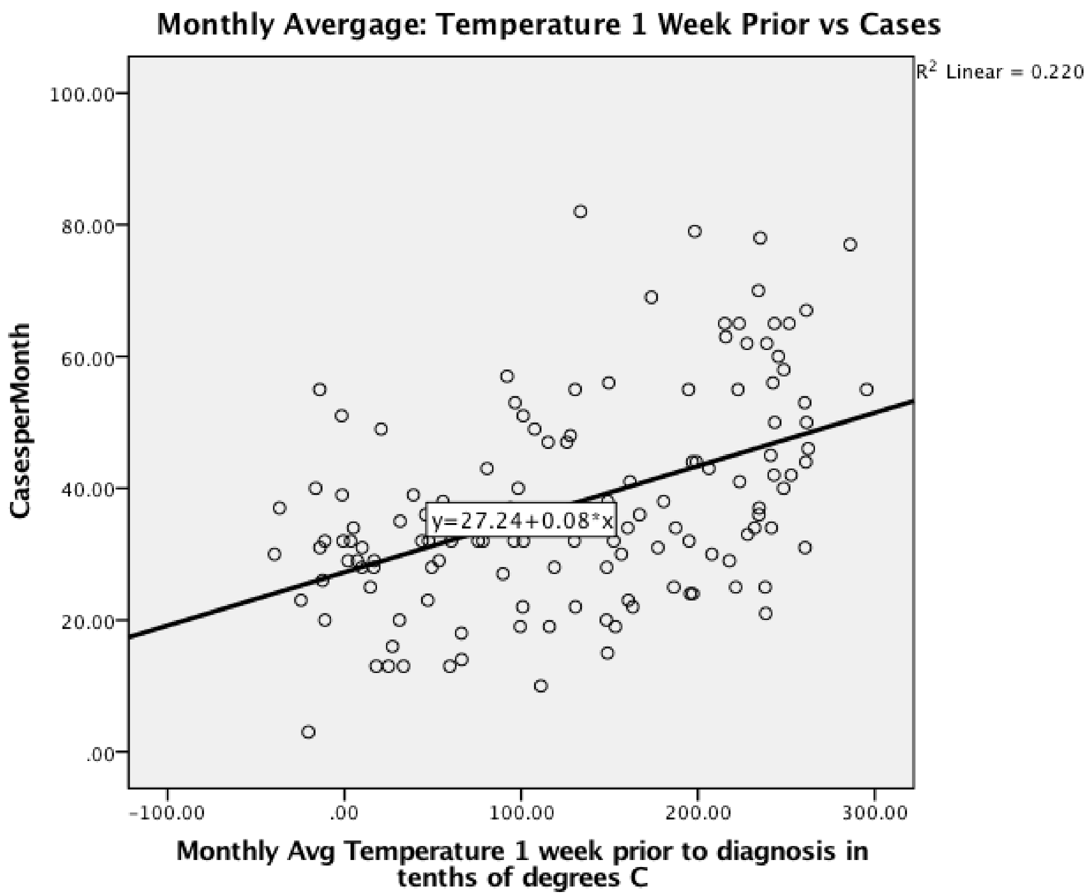

Figure 19. Week 1 temperature vs. cases per month giardiasis in Missouri.

Temperature 2 weeks prior to diagnosis. A linear regression analysis was conducted to evaluate the relationship between temperatures 2 weeks prior to diagnosis with giardiasis and number of cases per month of giardiasis in Missouri between 2003–2013. The scatterplot for the two variables (see Figure 20) indicates that the two variables are linearly related such that as overall temperature 2 weeks prior to diagnosis increases, cases of giardiasis in Missouri increases. The regression equation for predicting the number of cases of giardiasis per month is

Cases per month = 26.93 + 0.08(Week 2 temperature)

The 95% confidence interval for the slope [0.06, 0.11] does not contain the value of zero, and therefore temperature 2 weeks prior to diagnosis is significantly related to the cases per month of giardiasis in Missouri. Temperature 2 weeks prior to being diagnosed has a small impact on number of cases of giardiasis per month in Missouri. Accuracy in predicting cases per month of giardiasis was weak. The correlation between temperature 2 week prior to diagnosis and cases of giardiasis per month was .480. Approximately 23% of the variance in cases per month was accounted for by the linear relationship with the temperature 2 weeks prior to diagnosis with giardiasis. The results of the ANOVA test are significant, $F(1,130) = 38.96$, $p < .001$. The p value is less than .05, so the null hypothesis that there are no differences between groups was rejected (see Table 7). Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0.

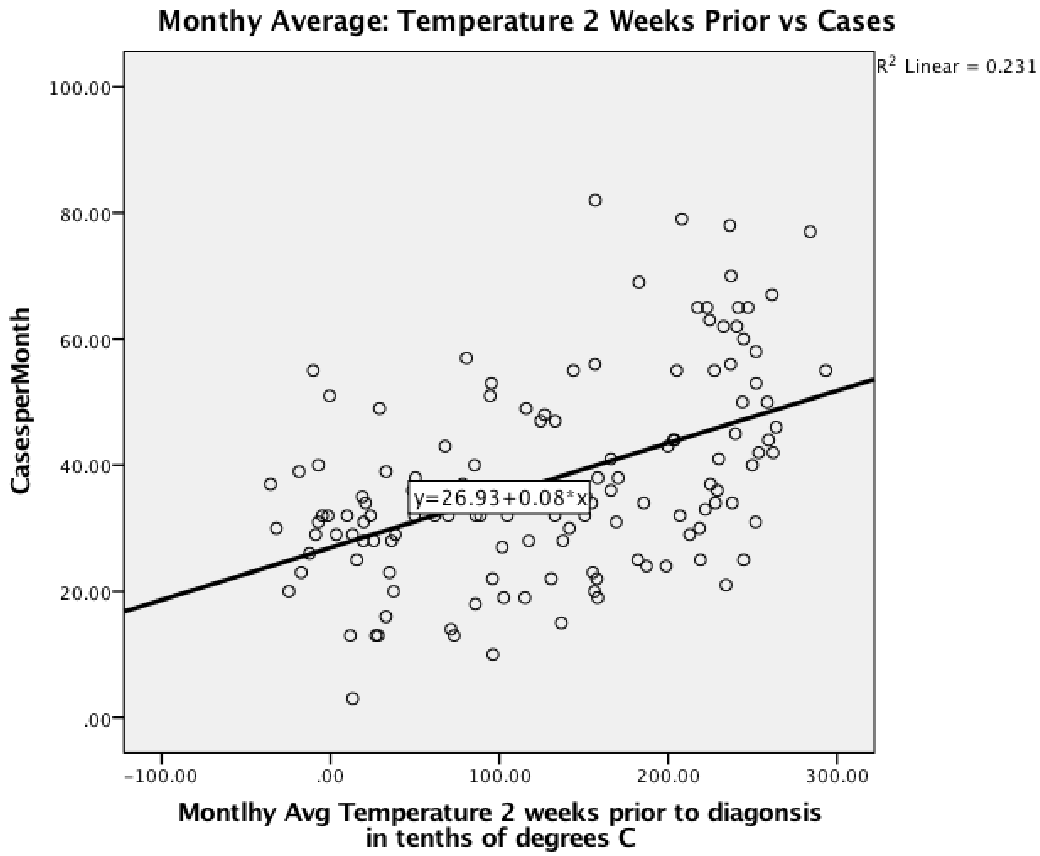

Figure 20. Week 2 temperature vs. cases per month giardiasis Missouri.

Research Question 3

Is there an association between CO_2 and the number of cases of giardiasis among residents of Missouri?

H_01: There is no association between CO_2 and the number of cases of giardiasis among residents of Missouri.

*H*a1: There is an association between CO_2 and the number of cases of giardiasis among residents of Missouri.

A linear regression analysis was conducted to evaluate the relationship between carbon dioxide (CO_2) in the air per month in Missouri to case and number of cases per month of giardiasis in Missouri between 2003–2013. The scatterplot for the two variables (see Figure 21) indicates that the two variables are linearly related such that as overall CO_2 increases, cases of giardiasis in Missouri increases. The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = -134 + 1.51(\text{Week 2 temperature})$$

The 95% confidence interval for the slope [0.83, 2.19] does not contain the value of zero, and therefore CO_2 per month in Missouri is significantly linearly related to the cases per month of giardiasis in Missouri. Carbon dioxide per month has a small impact on number of cases of giardiasis per month in Missouri. Accuracy in predicting cases per month of giardiasis was weak. The correlation between CO_2 in the air per month and cases of giardiasis in Missouri was .360. Approximately 13% of the variance in cases per month was accounted for by the linear relationship with the CO_2 per month in Missouri. The results of the ANOVA test are significant, $F(1,130) = 19.31$, $p < .001$. The p value is less than .05, so the null hypothesis that there are no differences between groups was rejected (see Table 7). Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0.

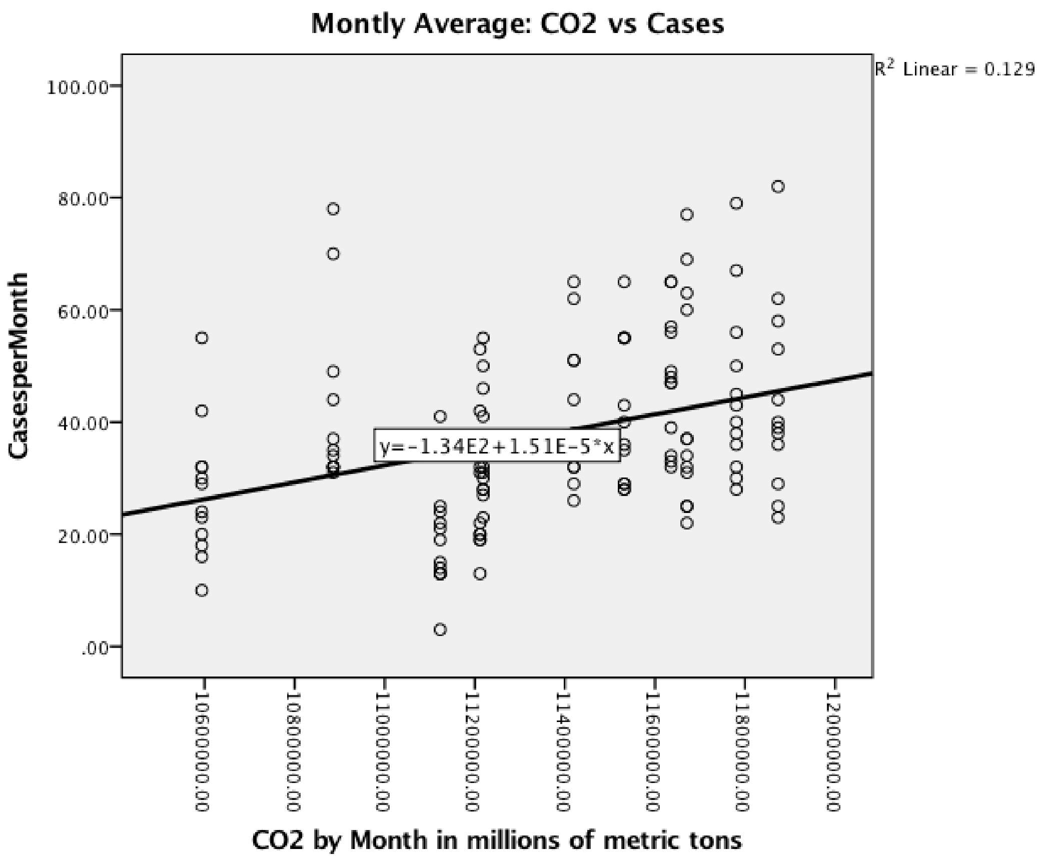

Figure 21. CO_2 per month vs. cases per month giardiasis Missouri.

Research Question 4

Is the association between precipitation and giardiasis modified by CO_2 levels?

$H_0$1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

H_a1: The association between precipitation and giardiasis among Missouri residents is not modified by CO_2 levels.

Precipitation 1 week prior to diagnosis and CO_2. A multiple regression analysis was conducted to evaluate how well environmental factors influenced cases of giardiasis per month in Missouri between 2003–2013. Predictor factors investigated were precipitation 1 week prior to diagnosis and CO_2 per month, and criterion factor was cases per month of giardiasis in Missouri. The linear combination of precipitation 1 week prior to diagnosis and CO_2 per month was significantly related to cases per month of giardiasis, $F(2,129) = 17.02$, $p < .001$. The sample correlation coefficient was .46, indicating that approximately 21% of the variance of cases per month of giardiasis in the sample can be accounted for by the linear combination of these environmental factors (See Table 8). The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = -127.688 - 1.776(\text{Week 1 precipitation}) + 1.520(CO_2)$$

As expected the precipitation value was negative and the CO_2 value was positive and both were significant ($p < .001$), meaning that as precipitation 1 week prior to diagnosis with giardiasis decreases and CO_2 per month increased, cases of giardiasis per month increased. The 95% confidence interval for the slope for precipitation 1 week prior to diagnosis and CO_2 per month do not contain the zero, therefore they are both significantly related to the cases per month of giardiasis in Missouri. Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0. Therefore, the null hypothesis that the association between precipitation 1 week prior to diagnosis with giardiasis and cases per month of giardiasis in Missouri is not modified by CO_2 levels, was rejected.

Table 8

Regression Analysis Results for Combined Variables

Combined Models with CO_2	Predictor Variables	B	95%CI	sr	p	R^2	F(2,129)
Precip1WK	Constant	-127.69	[-201.86, -53.52]		.001		
	P1WK	-1.78	[-2.75, -0.80]	-.28	<.001		
	CO_2	1.52	[0.87, 2.17]	.36	<.001	.21	17.0
Precip2WK	Constant	-127.04	[-202.19, -51.89]		.001		
	P2WK	-1.71	[-2.81, -0.61]	-.24	.003		
	CO_2	1.51	[2.17, 0.36]	.36	<.001	.19	15.0
Temp1WK	Constant	-144.20	[-211.49, -76.90]		<.001		
	T1WK	0.08	[0.06, 0.11]	.47	<.001		
	CO_2	1.51	[0.92, 2.10]	.36	<.001	.35	34.5
Temp2WK	Constant	-145.67	[-212.34, -79.01]		<.001		
	T2WK	0.08	[0.06, 0.11]	.48	<.001		
	CO_2	1.52	[0.93, 2.11]	.36	<.001	.36	36.4

Note. Dependent Variable: CasesperMonth

Precipitation 2 weeks prior to diagnosis and CO_2. A multiple regression analysis was conducted to evaluate how well environmental factors influenced cases of giardiasis per month in Missouri between 2003–2013. Predictor factors investigated were precipitation 2 weeks prior to diagnosis and CO_2 per month, and criterion factor was cases per month of giardiasis. The linear combination of precipitation 2 weeks prior to diagnosis and CO_2 per month was significantly related to cases per month giardiasis F(2,129) = 15.30, Precip2WK = p = .003, CO_2 = p < .001. The sample correlation coefficient was .44, indicating that approximately 19% of the variance of cases per month of giardiasis in the sample can be accounted for by the linear combination of these environmental factors (See Table 8). The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = -127.041 - 1.709(\text{Week 2 precipitation}) + 1.511(CO_2)$$

As expected the precipitation value was negative and the CO_2 value was positive and both were significant (Precip2WK = $p = .003$, $CO_2 = p < .001$), meaning that as precipitation 2 weeks prior to diagnosis with giardiasis decreases and CO_2 per month increased, cases of giardiasis per month increased. The 95% confidence interval for the slope for precipitation 2 weeks prior to diagnosis and CO_2 per month do not contain the zero, therefore they are both significantly related to the cases per month of giardiasis in Missouri. Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0. Therefore, the null hypothesis that the association between precipitation 2 weeks prior to diagnosis with giardiasis and cases per month of giardiasis in Missouri is not modified by CO_2 levels, was rejected.

Research Question 5

Is the association between temperature and giardiasis modified by CO_2 levels?

$H_0 1$: The association between temperature and giardiasis among Missouri residents is not modified by CO_2 levels.

*H*a1: The association between temperature and giardiasis among Missouri residents is modified by CO_2 levels.

Temperature 1 week prior to diagnosis and CO_2. A multiple regression analysis was conducted to evaluate how well environmental factors influenced cases of giardiasis per month in Missouri between 2003–2013. Predictor factors investigated were temperature 1 week prior to diagnosis and CO_2 per month, and criterion factor was cases per month of giardiasis. The linear combination of temperature 1 week prior to diagnosis and CO_2 per month was significantly related to cases per month giardiasis $F(2,129) = 34.51$, $p < .001$. The sample correlation coefficient was .59, indicating that approximately 35% of the variance of cases per month of giardiasis in the sample can be accounted for by the linear combination of these environmental factors (See Table 8). The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = -144.197 + 0.081(\text{Week 1 temperature}) + 1.511(CO_2)$$

As expected the temperature value was positive and the CO_2 value was positive and both were significant ($p < .001$), meaning that as temperature 1 week prior to diagnosis with giardiasis increased and CO_2 per month increased, cases of giardiasis per month increased. The 95% confidence interval for the slope for temperature 1 week prior to diagnosis and CO_2 per month do not contain the zero, therefore they are both significantly related to the cases per month of giardiasis in Missouri. Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0. Therefore, the null hypothesis that the association between temperature 1 week prior to diagnosis with giardiasis and cases per month of giardiasis in Missouri is not modified by CO_2 levels, was rejected.

Temperature 2 weeks prior to diagnosis and CO_2. A multiple regression analysis was conducted to evaluate how well environmental factors influenced cases of giardiasis per month in Missouri between 2003–2013. Predictor factors investigated were temperature 2 weeks prior to diagnosis and CO_2 per month, and criterion factor was cases per month of giardiasis. The linear combination of temperature 2 weeks prior to diagnosis and CO_2 per month was significantly related to cases per month giardiasis $F(2, 129) = 36.44$, $p < .001$. The sample correlation coefficient was .601, indicating that approximately 36% of the variance of cases per month of giardiasis in the sample can be accounted for by the linear combination of these environmental factors (See Table 8). The regression equation for predicting the number of cases of giardiasis per month is

$$\text{Cases per month} = -145.674 + 0.083(\text{Week 2 temperature}) + 1.519(CO_2)$$

As expected the temperature value was positive and the CO_2 value was positive and both were significant ($p < .001$), meaning that as temperature 2 weeks prior to diagnosis with giardiasis increased and CO_2 per month increased, cases of giardiasis per month increased. The 95% confidence interval for the slope for temperature 2 weeks prior to diagnosis and CO_2 per month do not contain the zero, therefore they are both significantly related to the cases per month of giardiasis in Missouri. Post-hoc tests were run using an online statistical calculator for linear regression (Soper, 2017). The observed statistical power for $p = 0.05$ was 1.0. The observed statistical power for $p = 0.01$ was 1.0. Therefore, the null hypothesis that the association between temperature 2 weeks prior to diagnosis with giardiasis and cases per month of giardiasis in Missouri is not modified by CO_2 levels, was rejected.

Summary

In chapter 4, the hypotheses proposed were tested using bivariate and multivariate analysis. The bivariate analyses tested the relationships between precipitation, temperature, and carbon dioxide (independent variables) and cases per month of giardiasis (dependent variable). The linear regression multivariate analysis tested two independent variables for correlations and covariates between temperature and CO_2, and precipitation and CO_2, as they act upon the cases per month of giardiasis variable. The results provided answers to the research questions. When independently tested, temperature, precipitation, and CO_2 were all significant variables affecting cases per month of giardiasis in Missouri. When the multivariate tests were run, they were also all significant variables associated in affecting cases per month of giardiasis in Missouri.

The first research question asked if there was an association between precipitation and the number of cases of giardiasis in residents of Missouri. The bivariate analysis showed that there was a significant relationship between precipitation and number of cases of giardiasis in residents of Missouri. This was true for precipitation measured 1 week prior to diagnosis (p = .001, R^2 = .08); and for precipitation measured 2 weeks prior to diagnosis (p = .005, R^2 = .06). There is a weak relationship between precipitation and cases per month of giardiasis in Missouri; therefore, the null hypothesis was rejected.

The second research question asked if there was an association between temperature and the number of cases of giardiasis in residents of Missouri. The bivariate analysis showed that there was a significant relationship between temperature and number of cases of giardiasis in residents of Missouri. This was true for temperature measured 1 week prior to diagnosis (p < .001, R^2 = .22); and for temperature measured 2 weeks prior to diagnosis (p < .001, R^2 = .23). There is a moderate relationship between temperature and cases per month of giardiasis in Missouri; therefore, the null hypothesis was rejected.

The third research question asked if there was an association between CO_2 and the number of cases of giardiasis in residents of Missouri. The bivariate analysis showed that there was a significant relationship between CO_2 and number of cases of giardiasis in residents of Missouri (p < .001, R^2 = .13). There is a weak relationship between temperature and cases per month of giardiasis in Missouri; therefore, the null hypothesis was rejected. It was thought that CO_2, precipitation, and temperature could be interacting. Further testing was needed to determine if these CO_2 was affecting the other two variables considered in this analysis.

The fourth research question asked if the association between precipitation and giardiasis was modified by CO_2 levels. The multivariate analysis showed that the variable of CO_2 was significant when added to the analysis for precipitation affecting cases per month of giardiasis. This occurred for both precipitation 1 week prior to diagnosis variable and for precipitation 2 weeks prior to diagnosis variable. For precipitation 1 week prior to diagnosis of giardiasis, both variables were significant (Precip1WK = $p < .001$, $CO_2 = p < .001$, $R^2 = .21$). For precipitation 2 weeks prior to diagnosis of giardiasis, both variables were significant (Precip2WK = $p = .003$, $CO_2 = p < .001$, $R^2 = .19$). The relationship between precipitation and cases of giardiasis per month was modified by CO_2, therefore the null hypothesis is rejected.

The fifth research question asked if the association between temperature and giardiasis was modified by CO_2 levels. The multivariate analysis showed that the variable of CO_2 was significant when added to the analysis for temperature affecting cases per month of giardiasis. This occurred for both temperature 1 week prior to diagnosis variable and for temperature 2 weeks prior to diagnosis variable. For temperature 1 week prior to diagnosis of giardiasis, both variables were significant (Temp1WK = $p < .001$, $CO_2 = p < .001$, $R^2 = .35$). For temperature 2 weeks prior to diagnosis of giardiasis, both variables were significant (Temp2WK = $p < .001$, CO_2 = $p < .001$, $R^2 = .36$). The relationship between temperature and cases of giardiasis per month was modified by CO_2, therefore the null hypothesis is rejected.

These results were interpreted in Chapter 5 by comparing these with the findings in the literature previously discussed in Chapters 2 and 3. Chapter 5 also includes the limitations of the study, recommendations, and implications of the study for positive social change. The final conclusion of the study is also in Chapter 5.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this cross-sectional retrospective quantitative study was to determine if temperature, precipitation, and CO_2 levels were associated with cases of giardiasis in Missouri. The dependent variable was cases per month of giardiasis of Missouri residents. For the purposes of this study, all probable and confirmed cases using the CDC case definition will be included, assuming Missouri residency. The independent variables were temperature (measured in tenths of degrees Celsius), precipitation (measured in millimeters), and CO_2 (measured in millions of metric tons). All variables aforementioned were coded as continuous variables. All tested variables showed significance. This study was conducted to add to the body of knowledge about how weather affects disease and specifically focuses on Missouri, a state not often reported on in the scientific community.

Interpretation of Findings

To the best of my knowledge, this is the first study that has been done including temperature, precipitation, and CO_2 as variables potentially associated with the number of cases of giardiasis in Missouri. The results showed that temperature, precipitation, and CO_2 are associated with cases of giardiasis per month in Missouri and can be used to predict number of cases per month of giardiasis in Missouri. There is not a significant difference between the results of one week prior to diagnosis averages and two weeks prior to diagnosis averages for temperature and precipitation variables. The results also show a gradual decrease in cases over the period sampled.

The independent variables (temperature, precipitation, and CO_2) all have different effects on the outcome variable cases of giardiasis per month in Missouri. The independent variable of precipitation showed a weak negative association with cases per month of giardiasis in Missouri. As the precipitation totals increased, the cases per month of giardiasis in Missouri decreased. Since most outbreaks of giardiasis occur through contaminated water supplies (Heymann, 2008), precipitation is an important variable to consider in a tributary state like Missouri, where many creeks, streams, and rivers flow together to create the usable water supply. Also, the cysts of *Giardia* can survive long periods outside of the host in hospitable conditions (Lydyard et al., 2010), which means they could be washed into a body of water with increased precipitation (Lujan & Svard, 2011). If one stream is contaminated, then an overabundance of precipitation could cause that contaminated stream to contaminate larger water sources. The precipitation variable was measured at one week prior to diagnosis and at two weeks prior to diagnosis because the incubation period for *Giardia* is 3 – 25 days, with an average of 7-10 days (Heymann, 2008).

Previous scientific literature has demonstrated that precipitation has been found to influence diseases in many areas of the world, such as New Zealand (Britton et al., 2010), Mexico (Colon-Gonzalez et al., 2013), Australia (Huang et al., 2013), and Botswana (Alexander et al., 2013). Within the United States of America, there has also been literature demonstrating the significance of precipitation affecting diseases (Curriero et al., 2001), such as Chicago (Lebl et al., 2013), Philadelphia (White et al., 2009), Florida (Shaman et al., 2002), Mississippi (2010), and the South-West (Kolivras & Comrie, 2004). Britton et al. (2010) found a positive association between precipitation and giardiasis in New Zealand. Significant associations were found with precipitation and cases of diarrheal disease in Botswana (Alexander et al., 2013). Curriero et al. (2001) found that waterborne outbreaks of disease have a strong correlation with extreme precipitation events during the same month. Greer, Ng, & Fisman (2008) suggest that with changes in precipitation patterns, vector borne and waterborne disease in in North America are likely to increase. Many diseases are impacted by precipitation, such as giardiasis; but there are many other factors that affect living organisms, and precipitation is not always a significant factor in predicting outbreak scenarios. Lal et al. (2013) found that there was no relationship between precipitation and incidence of giardiasis. In this research, precipitation was only weakly significant as a factor associated with cases per month of giardiasis.

The independent variable of temperature showed a positive association with cases per month of giardiasis in Missouri. As the temperature increased, the cases per month of giardiasis increased. It has been noted that giardiasis cases in the U.S.A. increase from early summer to early fall (Lujan & Svard, 2011), which corresponds to increases in temperature and increases in outdoor activity of Missouri residents. This research offers further support of the previous information on cases of giardiasis increasing from early summer to early fall.

The temperature variable was measured at one week prior to diagnosis and at two weeks prior to diagnosis because the incubation period for *Giardia* is 3 – 25 days, with an average of 7-10 days (Heymann, 2008). Giardiasis is spread through the consumption of the cyst form of the *Giardia* parasite cyst. This relates to temperature because the *Giardia* parasite in cyst form is affected by temperature. The cyst form of *Giardia* can survive at least one freezing cycle, and can survive for months in water with temperatures below 10 degrees Celsius (Environmental Protection Agency (EPA), 2000). Also, the cyst form of *Giardia* can withstand temperatures up to 54 degrees Celsius for a few minutes (EPA, 2000). After boiling water with *Giardia* cysts in it, no viable cysts will remain (EPA, 2000). *Giardia* cysts can remain viable for most of the year in Missouri, even with the great temperature changes between seasons, thriving best in the warmer summer season.

Previous scientific studies have demonstrated that temperature has been found to influence diseases in many areas of the world, such as New Zealand (Britton et al., 2010; Lal et al., 2013), Mexico (Colon-Gonzalez et al., 2013), Australia (Huang et al., 2013), Botswana (Alexander et al., 2013), and Hong Kong and Beijing, China (Bi et al., 2007). The Unites States of America has demonstrated the importance of temperature in disease rates in several areas as well, including Chicago (Lebl et al., 2013), Utah (Walton et al., 2010), and Philadelphia (White et al., 2009). Britton et al. (2010) found a positive association between temperature and giardiasis. Lal et al. (2013) found that there was no relationship between temperature and incidence of giardiasis; but temperature of the previous month was positively associated with cryptosporidiosis, and temperature of the current month was positively associated with Salmonellosis. Significant associations were found with minimum temperature and cases of diarrheal disease in Botswana (Alexander et al., 2013). Greer, Ng, & Fisman (2008) suggest that with increases in temperatures, vector borne and waterborne disease in in North America are likely to increase. Many diseases are impacted by temperature, such as giardiasis; but there are many other factors that affect living organisms, and temperature is not always a significant factor in predicting outbreak scenarios. In this research, temperature was moderately significant as a factor associated with cases per month of giardiasis.

The independent variable of CO_2 showed a positive association with cases per month of giardiasis in Missouri. As the CO_2 increased, the cases per month of giardiasis increased. The CO_2 variable was tested as a potential covariate for association and was paired with precipitation and also in another analysis with temperature. In both cases, the CO_2 variable showed significance and therefore must be considered a variable that is associated with cases per month giardiasis in Missouri. Research has shown that CO_2 and other greenhouse gasses can impact weather and cause increases in weather extremes including temperature and precipitation.

Carbon dioxide has often been used as an indicator for global climate change as it was in this study. The *Giardia* cyst is a hardy organism capable of resisting temperature extremes (low and high) and demonstrating a prolonged survivability outside the host organism for several months (Luan & Svard, 2011). The National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) have presented evidence that CO_2 is increasing in the atmosphere on average each year and this increase is affecting changing weather patterns (including temperature and precipitation) and a trending toward more extreme weather in many areas of the world. Weart (2003) and Epstein (2005) both elaborate on CO_2 in the atmosphere and its association with increasing non-endemic disease and the increase in the spread of vector borne disease. Anyamba et al. (2006) makes predictions based on climactic data gathered including CO_2, temperature, and precipitation data, that there will be a global increase in diseases due to climate change. In this study, CO_2 was confirmed to be a significant factor in association with cases per month of giardiasis in Missouri, as well as to have an effect on other environmental factors affecting cases per month of giardiasis in Missouri including precipitation and temperature.

The findings indicated that a decrease in precipitation and an increase in temperature are important factors for predicting an increase in cases per month of giardiasis in Missouri. The findings also indicate that an increase in CO_2 corresponds to an increase in cases per month of giardiasis in Missouri. When CO_2 was paired with precipitation the R^2 value increased, indicating a stronger model with both variables than either variable alone. A similar relationship was found to be true when CO_2 was paired with temperature, indicating a stronger model with both variables than either variable alone. Carbon dioxide is a significant variable in association with cases of giardiasis per month in Missouri. This supports the idea that global climate change may be affecting rates of giardiasis in Missouri.

Global climate change and how changes in weather affect disease in humans was the conceptual framework for the dissertation. Global climate change is, “any significant change in the measures of climate lasting for an extended period of time, including major changes in temperature, precipitation, or wind patterns that occur over several decades” (Environmental Protection Agency, 2013). It was thought that climate change brought about due to an increase in greenhouse gasses may be affecting the infection rate in Missouri; and it might also be putting evolutionary selective pressures on this organism leading to a change in infection rates different than has been seen before. This study included factors used to measure change in climate, such as precipitation, temperature, and CO_2 as independent variables. The conceptual framework of global climate change guided the study of the factors and the study of potential interactions of the factors influencing change in cases per month of giardiasis infection in Missouri. The results of this study show a significant association of CO_2 with cases per month of giardiasis in Missouri; as well as effect on other variables (temperature and precipitation) associated with cases per month of giardiasis in Missouri.

Limitations of Study

There were limitations to this cross-sectional study including the use of secondary data, the form some of the data were received, differences in subgroup reporting rates, and the manipulation of variables. One of the limitations was the reliability and completeness of secondary data from the Missouri Department of Health and Senior Services (MDHSS). Some of the data received was incomplete or missing requested variables, and these were not included in the analysis of variables. Also, giardiasis cases have officially been recorded for about 10 years, and the format for recording that data changed in 2009; so, the cases before 2009 could be classified differently than after 2009. This change did not affect any of the variables considered, but the diagnosis status. However, the inclusiveness of the definition may have changed the total number of reported cases. As all reported cases are included in this sample, this most likely had minimal impact on the results.

Further data were gathered from the National Climatic Data Center (NCDC), which included temperature maximum and minimum, and precipitation and snowfall totals. These data were provided by county and was so large that 4 data sets had to be sent separately. This led to problems with calculating the transition between data sets data (temperature and precipitation data for 1 week prior and 2 weeks prior). The transition data had to be calculated by hand, whereas all the other averages and calculations were done by a formula created and input into the excel data sheets. Data calculated by hand was checked multiple times, so human error was minimized. Data were transferred from the given data provided by NCDC and MDHSS and input into a new data sheet on Excel. This process added an element of human error to the research. Time was taken to confirm the correctness of data transfer and to check the data were transferred correctly.

Data were then condensed into monthly averages and transferred to another final data sheet in SPSS. This was also checked multiple times prior to analysis. There is the element of potential human error in this study that must be considered. Also, the weather information was given in conflicting forms for snowfall – given in millimeters, and precipitation given in tenths of millimeters. This required all data to be converted to millimeters, adding another element of potential human error. Temperature maximum and minimum were consistent in their given form of tenths of degrees Celsius. All of this complex data manipulation may affect the data validity and reliability, even though steps were taken to limit human error.

Data on carbon dioxide in the air was gathered from the Environmental Protection Agency. They provided a summary of data of reported CO_2 produced by companies in Missouri. These data were a yearly total that was then divided by 12 months and entered into the analysis. These data were problematic, in that there was no variation in the data from month to month within a yearly total, and this potentially led to a false result on the effect of CO_2 on cases per month and on its influence on the other variables of temperature and precipitation. The forms of these data were a limitation of the study.

Sampling and methodological considerations are also limitations of the study. Sample size is limited to that which was officially reported and recorded as a case according to the CDC definition, so any misdiagnosed or unconfirmed cases were not included. Every known case of giardiasis reported was used in this study, so this is the best possible outcome for the data analysis. However, there are always underreported or misdiagnosed cases that might not have been included in the sample. This was noted by the disparity in race, ethnicity, and rural/urban status reporting rates. Although these numbers somewhat coincide with the statistical population numbers of Missouri, it does make it unclear on if they are disproportionately affected by giardiasis.

Also, there are cultural and geographical difference between rural and urban populations, black and white populations, and Hispanic and non-Hispanic populations that might play a role in reporting rates that was not taken into account by this study. Cross-sectional studies are prone to some standard problems including finding a representative sample, having a large enough sample size, and data collection issues. This study had a very large sample size, but due to the nature of the disease, the sample collected was not representative of the population of the state of Missouri.

Also, there may have been problems with data collection or transcription. Human error is always a possibility when collecting secondary data. It is possible that the data were transcribed or entered incorrectly at any point along the collection line from initial collection, to compilation, to analysis. Non-response bias may also be a contributing factor in the outcome of this research. All available cases were used, but it is known that not all cases of disease are reported or correctly diagnosed. The large sample size was used as an attempt to compensate for these flaws in the methodological design.

Both outcome and exposure information is being assessed at the same point in time. Thus, there is no way of discerning exact temporality. Also, as global climate is changing, what weather predictions were used in the past may not be appropriate for the future. This is something the model will need to take into account. This study intentionally limited the number of factors as it was an initial study and that may skew the results. If more factors were considered, then perhaps a more accurate model could be made, but the purpose of this study is an initial study, so limiting factors was important.

Recommendations

The results of this study contributed to the limited body of knowledge about giardiasis cases, climatic variables, and disease reports in the Midwest, including Missouri. There are many opportunities for further research in this area.

Future Research

More studies are needed to understand the effects of precipitation and temperature on diseases case rates in Missouri. Because Missouri is a tributary state, there is a significant possibility that similar studies could be done on different waterborne diseases and result in significant findings. Other diseases to consider that may be more affected by temperature and precipitation include: *Escherichia coli, Salmonella, and Cryptosporidium,* which are all diseases monitored by the Missouri department of Health and Senior Services. Lal et al. (2013) found that temperature of the previous month was positively associated with cryptosporidiosis, and temperature of the current month was positively associated with Salmonellosis. These studies could be performed also in the surrounding states of the Midwest, an underserviced area medically and underreported scientifically. These studies could lead to predictive formulas that could save lives in Missouri.

In addition to studies on precipitation and temperature, more studies are needed to determine if climate change is affecting disease rates in Missouri and throughout the Midwest of the United States. Carbon dioxide is just one of many factors that could be used as a variable to measure climate change. Other factors that could be investigated include other greenhouse gasses, seasonal changes, snow cover, temperature, precipitation, biomass, sea level, solar activity, volcanic eruptions, and chemical composition of soil or water (Weart, 2003; American Institute of Physics, 2013). Future studies should include variables in forms that are more representative of the changes throughout the year of seasons, which greatly affect the Midwest.

Practice

Giardiasis is a disease that is often misdiagnosed and is commonly underreported. This organism is a difficult organism to rid from the environment, and therefore can continue to plague areas once affected by the disease. Using the data provided by the CDC for the total giardiasis counts, costs, rates, and percentages, it can conclusively be said that the Midwest of the United States of America has the highest number of cases of giardiasis in 2010; n = 5,417 cases in 2010 (Yoder et al., 2012). This means that almost one third (27.2 %) of all cases of giardiasis in the United States that were reported at a rate of 11.4 in the year 2010 came from the Midwest (Yoder et al., 2012). More research is needed to determine what factors actually influence giardiasis in the Midwest. The Midwest states have a unique climate and culture that make them different from other areas in the United States and throughout the world. There were factors that could be examined further to include race, ethnicity, age, and many socio-economic factors that could influence the high number of cases in children age 10 and below. This area needs to be investigated further to determine what are the most important factors in the spread, transmission, and re-occurrence of giardiasis in the Midwest. Once these factors are known, then prevention methods can be taken to prevent further death and disease.

Implications

The findings of this study have the potential to spur on further studies into climate and disease, as well as into giardiasis, and diseases in the Midwest. This study has highlighted the need for further studies into the variations in rural and urban reporting rates of disease in Missouri, as well as race and ethnicity differences. This study has provided a better understanding of the impact of precipitation, temperature, and CO_2 differences on disease case rates in Missouri. This study has also highlighted the need for a more precise measure for CO_2 in the air to be used in further studies. The implications for positive social change include the use of the results presented within this study by public health agencies and environmental agencies in the in Missouri and the Midwest to use evidence based research to make informed decisions about public health and the allocation of resources prior to and during a disease outbreak.

Another social change implication is policy change. When the temperature (because it was the most significant variable of interest in this research) is at levels that are conductive to the spread of giardiasis, public water recreational sites that could potentially be contaminated could be closed to the public until they can be cleared for giardiasis or other waterborne contamination. This should also extend to the inspections of public and private wells in the areas of suspected contamination. This could help raise awareness in the communities at risk and through local businesses to help prevent morbidity and mortality through contaminated drinking water. It is hoped that this will allow public health and environmental agencies to allocate resources to testing wells and closing public waterways appropriately.

Another implication for social change is to increase and update the knowledge about giardiasis in the Midwest and encourage further research. This study is the first known research to investigate weather influences on disease in Missouri. There are many other factors that need to be investigated to form a comprehensive understanding of giardiasis and other diseases in the Midwest. Risk factors need to be evaluated and associative variables need to evaluated to assist in forming effective prevention methods for diseases in the Midwest.

Conclusions

To the best of my knowledge, this study is the first to associate and regress the relationship between cases per month of giardiasis with climatic variables (temperature, precipitation, and CO_2) in Missouri. The results of this study suggest that temperature, precipitation, and CO_2 are associated with cases per month of giardiasis in Missouri. Temperature was the most significant factor in this study, and as temperature increases, case numbers of giardiasis increase. Carbon dioxide and precipitation were also found to have a significant effect on cases per month of giardiasis in Missouri.

Some researchers found that precipitation was an important variable associated with diseases (Britton et al., 2010; Colon-Gonzalez et al., 2013; Huang et al., 2013; Lebl et al., 2013; Alexander et al., 2013; Curriero et al., 2001; White et al., 2009; Shaman et al., 2002; and Kolivras & Comrie, 2004). This researcher found that precipitation was very weakly negatively associated with cases per month of giardiasis in Missouri. The nature of the cyst form of this parasite is very hardy and can survive long periods outside the host and can withstand dry conditions. Precipitation may have more influence on other diseases that are more receptive to precipitation variation.

Other researchers found that temperature was an important variable associated with disease (Britton et al., 2010; Lal et al., 2013; Colon-Gonzalez et al., 2013; Huang et al., 2013; Lebl et al., 2013; Walton et al., 2010; Alexander et al., 2013; Bi et al., 2007; and White et al., 2009). This researcher found the most significant variable of interest was temperature, which was moderately positively associated with cases per month of giardiasis in Missouri. Public Health and Environmental Agencies should be aware that as temperature increases, case rates of giardiasis are likely to increase. Careful observation of waterways and drinking water should occur at peak temperature seasons.

Many researchers indicated CO_2 as an important variable associated with disease. Carbon dioxide is just one measure of climate change. There are many other measures of climate change that can be, and should be used, in future research. This researcher found a significant association with CO_2 in the air and cases of giardiasis in Missouri. Carbon dioxide was also found to increase the R^2 value of other variables (precipitation and temperature) in association with cases per month giardiasis in Missouri. The *Giardia* parasite is a hardy parasite and the variable of CO_2 may not have been sufficient to influence case rates of giardiasis as much as expected. That does not mean that other diseases may not be influenced by CO_2 rates or other measures of climate change.

Giardiasis is considered a re-emerging disease in the United States and should be carefully observed in the future. There are many forgotten diseases that are re-appearing in the United States due to a great many factors including immigration, introduction of non-native species, and an increase in vectors to transmit other diseases. The Midwest has long been neglected in scientific research concerning waterborne diseases, climatic effects on disease, and re-emerging diseases. This research has narrowed the gap in the research in many areas including disease rates in the Midwest, giardiasis research in the United States, climate change variables affecting health, and weather effects on disease rates. This research conducted concerning weather and diseases could lead to positive social change through policy changes and reduction in morbidity and mortality from waterborne diseases in the Midwest. It is time for more studies to be done concerning the Midwest before a large outbreak situation occurs that could have been prevented.

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Appendix A: MDHSS Exemption Letter

Missouri Department of Health and Senior Services
P.O. Box 570, Jefferson City, MO 65102-0570   Phone: 573-751-6400   FAX: 573-751-6010
RELAY MISSOURI for Hearing and Speech Impaired 1-800-735-2966   VOICE 1-800-735-2466

Gail Vasterling
Director

Jeremiah W. (Jay) Nixon
Governor

November 24, 2014

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Walden University
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Minneapolis, MN 55401

Karin Bosh
Department of Health and Senior Services
P.O. Box 570
Jefferson City, MO 65102

RE: Effects of Temperature and Rainfall on Giardiasis in Missouri

Dear Ms. Calderas and Bosh:

I have reviewed your proposed project entitled "Effects of Temperature and Rainfall on Giardiasis in Missouri". This project is exempt from the requirement for a full review by the Institutional Review Board (IRB) based on 45 CFR 46.101(b)(4). The research involves the study of existing data and the information will be recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

Please notify me immediately if any significant changes occur to your project that may change its IRB exemption status.

Sincerely,

Sharon Ayers
Chair
Institutional Review Board

c Amy Forbis
   Lisa Brown
   Harold Kirbey
   Gail Vasterling

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Appendix B: Census Rural vs. Urban Classification of Counties

Core Based Statistical Areas, Counties, Independent City, and Principal City