THE ASSOCIATION BETWEEN SEASON AND CRITICAL FOOD SAFETY VIOLATIONS IN SAN DIEGO COUNTY RETAIL FOOD FACILITIES

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ABSTRACT OF THE THESIS

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Public health is expected to be adversely affected by climate change. One aspect is rising temperatures that will directly and indirectly impact the biological mechanisms that propagate the spread of disease. Future summer heat waves are projected to increase in frequency, intensity, and duration, reaching historic temperatures by the end of the century. While previous studies have found links between increased ambient temperatures and increased cases of foodborne illness, the role of critical temperature violations in retail food facilities has not been clearly established. Improper hot and cold holding temperatures of potentially hazardous foods is one of the 5 major predictors of foodborne illness according to the CDC. In this study the association between daily maximum temperatures over the 2 year study period of 2013-2014 and holding temperature violations was examined. Inspection and violation data for the 2-year period was obtained from the County of San Diego’s Department of Environmental Health. When rates of temperature violations were examined, days with maximum temperatures greater or equal to 20°C, 25°C, and 30°C were associated with higher rates of violations (p<0.05). In analysis by season, the combined summer months of June, July, and August had significantly higher rates of temperature violations per inspection in comparison to the remaining months of the year (p<0.001). As San Diego has episodes of extreme hot weather (e.g. Santa Ana winds) in winter months as well, an analysis was conducted to determine if unusually hot days (as compared to the historical average maximum temperature) of the 2 study years were associated with a greater rate of violations, however, no association was found. In a nation where restaurants play a large role in consumer culture, environmental changes impacting food safety maintenance of retail food facilities have the potential to adversely affect the state of public health. This study, while being limited in a the lack of a direct assessment of cold holding temperature violations, suggests that future efforts should be focused on increased surveillance and better monitoring of food-handling practices that prevent the propagation of diseases attributed to retail food facilities affected by the changing state of the environment.
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CHAPTER 1

INTRODUCTION

Climate change is thought to have a potential effect on food safety throughout the various parts of the food chain process, beginning with production and ending in consumption (Tirado, Clarke, Jaykus, McQuatters-Gollop, & Franke, 2010). Factors that play a role in affecting food safety include meteorological changes such as temperature and precipitation, and increased frequency and intensity of unusual or extreme weather events (Tirado et al., 2010). Temperature and precipitation changes have affected the incidence of certain bacteria, viruses, and parasites in relation to their role in foodborne illnesses (Tirado et al., 2010). Climate change has both direct and indirect impacts on food safety principles by affecting animal production and animal health, as well as the processing and handling of foods (Tirado et al., 2010). Increases in temperature as they relate to increased rates of salmonellosis and campylobacteriosis have been found in studies conducted in Canadian, Australian, and European populations, where some studies have found linear associations between temperature and cases after specific temperature thresholds are exceeded (Tirado et al., 2010). Temperature associations with food-borne illnesses have been studied and trends have been found, but associations between temperature and seasonal patterns and restaurant cold holding temperature violations have been limited in study.

According to Statista, a comprehensive international statistics database, estimates for US consumers in 2013 found that nearly 83% of consumers visited quick service restaurants and over 68% visited casual dining restaurants at least once a week (Statista, n.d.). The retail food industry plays a large role in modern consumer culture, and, thus, threats to food safety should be further investigated as a serious public health issue. While infectious gastroenteritis and diarrheal illness in developed countries may have a low mortality rate, the morbidity rate remains high, which creates a large scale social and economic burden (Onozuka, Hashizume, & Hagihara, 2010). The economic toll that foodborne illness takes in
regards to a diminished state of well being, the loss of productivity, and all of the associated medical costs ranges from estimates of 10 to over 80 billion a year (U.S. Food and Drug Administration [FDA], 2013). Foodborne illness is also subject to a high degree of underreporting, as less severe cases go undetected and as the role of foodborne transmission can be obscured by pathogenic transmission through other pathways such as water sources or person-to-person contact (FDA, 2013).

While there are various ways that food can be contaminated early in the food chain process, proper handling of contaminated food is a crucial factor that can decrease the potential for an outbreak to occur (Centers for Disease Control and Prevention [CDC], 2015a). Restaurant food safety relies on set standards that govern sanitation and proper temperature conditions, and are based on scientific knowledge of pathogenic microorganisms that have the potential to seriously affect human health following exposure to contaminated food. Restaurant inspections provide information on the operations and procedures at a food facility (Phillips, Elledge, Basara, Lynch, & Boatright, 2006). Routine restaurant inspections serve an important role in preventing foodborne illness from improper food handling and preparation practices (Cruz, Katz, & Suarez, 2001).

Improper holding temperatures remain in the top five risk factors perpetuating foodborne illness within retail and food service establishments, according to epidemiological outbreak data (FDA, 2013). The threat of climate change and changing meteorological conditions brings with it predictions of more heat events that are unusual in either temperature or duration for a given geographic area. It is likely, based on the importance of cold-holding temperatures to foodborne illness (Gould, Rosenblum, Nicholas, Phan, & Jones, 2013; FDA, 2009; OC Environmental Health, n.d.) that there will be an increase in these violations if ambient temperature increases. An increase in violations will have a direct public health impact through morbidity and mortality from infections associated with improper temperature controls in retail food facilities. A better understanding of the role environmental factors play in disease progression will be an effective prescriptive tool in improving warning systems and outbreak detection (Onozuka et al., 2010).
OBJECTIVE

The objective of this thesis was to determine if any relationship exists between higher daily average maximum temperatures, as recorded by the Montgomery Field Station in San Diego County, and an increase in the rate of hot and cold holding temperature violations per inspection observed in restaurant food facilities in San Diego County over the two-year period from 2013-2014.
CHAPTER 2

REVIEW OF THE LITERATURE

FOODBORNE ILLNESS IN THE UNITED STATES

The CDC (2015a) estimates that, 1 out of 6 Americans get sick annually from a contaminated food or beverage source. Foodborne diseases, of which more than 250 have been identified, are caused by infection from bacteria, viruses, and parasites (CDC, 2015a). Common bacterial illnesses are caused by infection with Campylobacter, Clostridium perfringens, Escherichia coli, Salmonella, and Listeria. Common viral foodborne diseases include norovirus, rotavirus, and Hepatitis A. Parasitic foodborne diseases include cryptosporidiosis, giardiasis, toxoplasmosis, and trichinellosis (CDC, 2015a). As the pathogens enter the body via the gastrointestinal tract, the initial symptoms usually manifest there, and while symptoms differ between the various diseases, common symptoms of foodborne infection include nausea, fever, vomiting, abdominal cramps, and diarrhea (CDC, 2015a). The incubation period varies depending on the specific etiological agent, and can range from hours to weeks (CDC, 2000).

According to the CDC (2014), approximately 48 million people each year are affected by a foodborne illness. Estimates indicate that the most common foodborne illnesses are caused by norovirus and the illnesses that result from the infection with the bacteria Salmonella, Clostridium perfringens, and Campylobacter. The top five pathogens causing domestically acquired foodborne illness are, in descending order, norovirus, nontyphoidal Salmonella, Clostridium perfringens, Campylobacter spp., and Staphylococcus aureus. The top five foodborne pathogens that resulted in hospitalization were nontyphoidal Salmonella (35%), norovirus, Campylobacter spp., Toxoplasma gondii, and E.coli (STEC) 0157. The pathogen that resulted in the most deaths was nontyphoidal Salmonella, at nearly 30% (CDC, 2014). The CDC (2015b) approximates that one million cases of foodborne illness are caused
by infection with *Salmonella* each year, resulting in approximately 19,000 hospitalizations and 380 deaths.

For the years 1993-2000, there were close to 3,000 foodborne hospitalizations in Los Angeles—roughly a third of all foodborne disease hospitalizations in California during that period of time (Simon et al., 2005). For both Los Angeles County and the rest of California, infection from *Salmonella* was found to be the most frequently reported discharge diagnosis; the second most frequent foodborne illness diagnosis was infection from *Campylobacter* (Simon et al., 2005).

**Restaurant-Acquired Foodborne Illness**

In an analysis of CDC data for foodborne disease outbreaks, of 9,040 outbreaks reported between 1998 and 2004, 52% were associated with restaurants—including delicatessens, cafeterias, and hotels (Angulo & Jones, 2006). FoodNet conducted a large telephone survey during the years 1998-1999 that involved 12,755 people, with 12,052 total included in the study (Angulo & Jones, 2006). FoodNet, the Foodborne Disease Active Surveillance Network, is a collaborative effort between various agencies such as the CDC, FDA, U.S. Department of Agriculture (USDA), and 10 states that aims to collect information on foodborne illness cases to determine the origin and spread of outbreaks (FDA, 2015b).

About 9% of people who reported eating at a fast food establishment 5 or more times in the past week also reported that they had experienced gastrointestinal illness in the month prior; for those that ate at fast food restaurants less than 5 times a week, this number experiencing gastrointestinal illness in the month prior was approximately 5% (relative risk 1.7, 95%, CI 1.36-2.13; Angulo & Jones, 2006). However, an association between increased frequency of visiting restaurants that offered full-service and diarrheal illness was not found (Angulo & Jones, 2006).

A related article stated that of 457 foodborne disease outbreaks reported by FoodNet sites in 2006 and 2007, 66% were attributed to restaurant settings, and 34% of those outbreaks were attributed to food preparation practices (Gould et al., 2013). 95% of the total outbreaks were attributed to a single etiology, the most frequent being from norovirus (60%), and the second highest from *Salmonella* (13%; Gould et al., 2013).
A study focusing on Ontario, Canada summarized data related to gastrointestinal illnesses reported to authorities from 2007-2009 (Vrbova, Johnson, Whitfield, & Middleton, 2012). Of approximately 30,000 gastrointestinal illness cases reported to the health authorities within those years, about 10,900 cases, or 36.5%, were caused by campylobacteriosis, and about 7,500 cases, or 25%, were caused by salmonellosis. Domestic cases of campylobacteriosis, cryptosporidiosis, giardiasis, salmonellosis, and VTEC-illness showed peaks in incidence of diseases in the summer month of July and August. The most common reported source of infection where exposure was known was food (approximately 54%). Of those that were food related, nearly one third (29.7%) of the cases were found to be attributed to the exposure settings of retail food premises—including restaurants, grocery stores, bakeries, delis, caterers, and mobile food premises (Vrbova et al., 2012).

**SOURCES OF FOOD CONTAMINATION**

Foodborne microbes are found in the intestines of healthy animals raised for food (CDC, 2015a). Contamination of meat and poultry carcasses can occur during slaughter, where there is contact with intestinal contents. Fruits and vegetables can be contaminated if they are washed or irrigated with contaminated water (from animal manure or human sewage). Hens carrying salmonella in their ovaries can transfer it to the eggs before they are formed (CDC, 2015a).

Later in the food processing process, contamination may be introduced from improper food handling practices, or cross-contamination from non-sanitized equipment or infected raw foods (CDC, 2015a). Infection from *Shigella* bacteria, Hepatitis A virus, and norovirus can occur from improper handling of foods, such as infected food handlers’ unsanitary or inadequate hand washing practices (CDC, 2015a).

Following contamination, food handling processes also determine the occurrence of a foodborne outbreak (CDC, 2015a). Allowing bacterial microbes to multiple to a point where they will pose a threat to human health is a consequence of inadequate temperature control. Properly refrigerating and freezing foods generally prevents the microbes from multiplying, and allows the bacteria to exist in a dormant stage, although this does not apply to *Listeria monocytogenes* or *Yersinia enterocolitica* bacteria, which thrive in cold temperatures.

Microbes are generally effectively killed by heating to high temperatures, except for some
pathogens like *Clostridium* bacteria that produce heat-resistant spores only killed at above boiling point temperatures (CDC, 2015a).

**CONTRIBUTING FACTORS IN A FOODBORNE OUTBREAK**

According to the CDC (2000), a foodborne illness outbreak is defined (since 1992) as an incident where two or more people have a similar illness after ingestion of a common food. Confirmation of foodborne disease outbreak from a specific etiologic agent is often made through the isolation of the agent from the clinical specimen from two or more infected people, or from the specific epidemiologically implicated food (CDC, 2000).

The top five risk factors associated with foodborne illness are improper hot/cold holding temperatures of potentially hazardous foods, improper cooking temperatures of foods, dirty and/or contaminated utensils and equipment, poor employee health and hygiene, and food from unsafe sources (FDA, 2013; OC Environmental Health, n.d.). Each of these is considered a major violation that is most commonly attributed to foodborne illness outbreaks. According to the Cal Code (San Diego County, n.d.b), potentially hazardous foods should be monitored to minimize the time they are spent in the danger zone, between 41°F and 135°F, a temperature zone that facilitates the growth of pathogenic bacteria. Improper cooking temperatures of foods allows for the survival of pathogenic bacteria on various foods such as raw poultry, raw ground meats, raw pork, fish, eggs, lamb, and fruits and vegetables. Contaminated utensils or equipment that have not been adequately or frequency cleaned or sanitized can lead to cross contamination. Poor employee health and hygiene allows for the employee to infect the consumer through the contamination of the foods that are mishandled. Lastly, all food products that are to be used in the making of food that will eventually be sold or consumed should be checked to ensure it is from safe, approved sources (OC Environmental Health, n.d.).

Gould et al. (2013) states that there were 32 contributing factors identified that either enable or allow propagation of an outbreak, based on analysis of restaurant-associated foodborne illness outbreaks as reported by FoodNet. These 32 factors were divided into the three categories of contamination factors, proliferation or amplification factors, and survival factors (Gould et al., 2013). Essentially, these factors are differentiated by those that introduce the pathogen into the environment, those that allow the pathogen to grow, and
those that fail to inactivate the agent, thus leading the way for its survival (Gould et al., 2013). Approximately 25% of the total 457 outbreaks analyzed in the study were reported to be caused by proliferation factors, and particularly, factors such as inadequate cold-holding temperatures and slow cooling, attributed to 47 and 34 outbreaks, respectively (Gould et al., 2013). Compromised food preparation practices including time and temperature controls were found to be most commonly associated with outbreaks of *E. Coli* 0157, *C. perfringens*, and *Salmonella*, with 100%, 81%, and 58% of infections, respectively (Gould et al., 2013). The three most common ways contributing factors were assessed were, in descending order, environmental inspection, interview with food operator or food worker, and a review of the food preparation practices (Gould et al., 2013). In the case where food handling practices were the cause of infection, the contributing factors were determined mainly by environmental inspection and food preparation review (Gould et al., 2013).

In 2008, the FDA’s National Retail Food Team conducted the final phase of a 10 year study to examine CDC risk factors for foodborne illness outbreaks by conducting data collection inspections of foodservice and retail food facilities (FDA, 2009). The previous two reports emphasized the need to focus on trouble areas, of which cold holding of potentially hazardous foods was a major issue; this risk factor was also observed in the final 2009 report as being frequently out of compliance. In each phase of the study, data was collected during visits of over 800 facilities in 9 different facility types, in which both observations and communication with the personnel at the establishment comprised the data collection. For the category of fast food restaurants, 68% of 103 observations found that the risk factor attributed to potentially hazardous foods (PHF) held cold at 41°F or below was out of compliance. For full-service restaurants, 71.9% of a total 96 observations were found to be noncompliant for cold holding temperatures. Recommendations for the retail food facilities included developing SOPs that address the risk factors and emphasize critical limits of specific food safety hazards; providing the necessary resources and equipment (temperature measurement devices, temperature logs, sanitizing equipment) addressed in the SOPs; ensuring monitoring procedures are being followed by the employees; and implementing periodic review and reassessment of SOPs if necessary. Recommendations for regulatory retail food protection programs included developing procedures that focus the inspection on risk factors most associated with foodborne illness; ensuring the inspector has the appropriate
equipment and documentation to conduct the inspection; having a more interactive approach to educating operators of the facilities inspected; and developing consistent enforcement protocols for facilities exhibiting non-compliances (FDA, 2009).

**LOCAL, STATE, AND FEDERAL REGULATIONS REGARDING FOODBORNE ILLNESS PREVENTION**

The occurrence of an outbreak of foodborne illness is initially detected by local and state health agencies, which identify and investigate foodborne illness cases that have been reported to health care providers, clinical laboratories, or by the individuals themselves (FDA, 2015b).

The FDA plays a role in outbreak investigation when an FDA-regulated product—all products besides those regulated by the USDA such as meat, poultry, and certain egg products—is predicted to be the cause of the foodborne outbreak (FDA, 2015b).

State agencies are responsible for analyzing routine disease surveillance reports, working together with local health agencies, and reporting cases to the CDC, a federal entity (FDA, 2015b). The CDC uses FoodNet and PulseNet to bridge connections between reported cases of foodborne illness. PulseNet, a project that involves the CDC, FDA, USDA, state and some local health departments, uses a national computer network to find patterns in disease outbreaks by identifying the suspected pathogen and linking similar cases through DNA fingerprinting analysis (FDA, 2015b).

The California Department of Public Health (CDPH) is the state department that consists of various sub-departments, including the Center for Environmental Health, that are responsible for the general health of California residents.

The responsibility of conducting inspections of food retail establishments lies with local health agencies. The local agencies have the role of protecting people from foodborne illnesses caused by serious food safety violations in food service establishments. The Department of Environmental Health (DEH) is the local department in charge of regulating retail food safety in San Diego. The DEH’s Food and Housing division conducts over 39,000 restaurant and food truck/cart inspections each year and issues restaurant grades for approximately 12,000 retail food establishments, including 6,000 restaurants (San Diego County, n.d.a, n.d.b). The purpose of restaurant inspections is to prevent foodborne illness
(Phillips et al., 2006). Routine inspections focus on compliance with state and local laws, including the California Retail Food Code (Cal Code; San Diego County, n.d.b). It is stated in the California Retail Food Code that enforcement of the provisions should be the duty of the local enforcement agency.

RESTAURANT INSPECTION VIOLATIONS AND PREVENTION OF FOODBORNE DISEASE

In the first study to attempt to determine whether routine inspection results are associated with reported foodborne outbreaks, a 1989 case-control study found that restaurants receiving poor routine inspection scores and that had critical violations were at an increased risk of having a foodborne outbreak (Irwin, Ballard, Grendon, & Kobayashi, 1989). According to the FDA Food code, critical violations are ones that are more likely to contribute to foodborne disease transmission (Jones, Pavlin, LaFleur, Ingram, & Schaffner, 2004). The inspection form at the time had 42 types of violations, including critical violations relating to proper cooling; reheating and holding temperatures of potentially hazardous foods; food handling practices; the health and hygienic practices of those handling the food; and equipment and utensil sanitation. At the time, the Seattle-King County Department received around 700 complaints of foodborne illness annually, each of which were further investigated to determine if it met the definition of foodborne illness outbreak, and to determine other pertinent factors related to the illness. For the most part, the study matched each case with two control restaurants, which were permanent restaurants with an active permit and no reported foodborne outbreak between Jan 1, 1986 and March 31, 1987. Results revealed that an average of about 3 people were affected in a foodborne outbreak episode; poultry was the most common infectious vehicle found; and the most common cause of outbreaks was attributed to improper temperatures of potentially hazardous foods during cooking, cooling, reheating, holding, or storage. It was also found that case restaurants had a significantly lower average inspection score than control restaurants, with scores of 83.8 and 90.9, respectively. Restaurants with a score of 86 points or less were approximately 5 times more likely to have had an outbreak than those with scores above 86. Restaurants with violations relating to improper food practices such as improper temperature controls of potentially hazardous foods, improper storage and handling of equipment, and other critical
violations had a significantly increased risk of an outbreak. The factor of “Any improper food protection practice,” covering a total of 11 violations, had an odds ratio of 15.8 (95% C.I. 2.0 to 124.1). The factor “Any critical violation” had an odds ratio of 6.3 (CI 1.8 to 22.5). The specific violation relating to improper temperatures of potentially hazardous foods during storage, display, service, transport, and hot and cold holding had an odds ratio of 10.1 (95% CI 2.2 to 45.7; Irwin et al., 1989).

One significant factor noted by the authors of the study was that the inspection form used in Seattle-King County placed more weight on improper temperature control violations than the forms used by other districts and FDA at the time (Irwin et al., 1989). Results also noted that there might be the possibility of inconsistency of inspection data due to the variations attributed to different sanitarians performing the inspections (Irwin et al., 1989).

An issue with this Seattle-King study noted by Cruz et al. (2001) was that, since the year of the study, Hazard Analysis and Critical Control Point (HACCP) guidelines have been introduced and established as a significant component of food safety and monitoring by the food industry (Cruz et al., 2001). Inspection forms and critical violations may not reflect the food safety issues relevant today in regards to foodborne illness associated with restaurants (Cruz et al., 2001).

A study conducted in Oklahoma, where inspections are conducted to adhere to the state food code, adapted from the US model Food Code, collected random samples of inspection files from inspections conducted between 1996 to 2000 in Oklahoma County and 30 counties in the Oklahoma State Department of Health (OSDH) jurisdiction (Phillips et al., 2006). The inspection form used at the time listed 44 items that could be possible violations, with 13 of those considered critical violations, such as “holding temperature correct.” This was the format of the inspection report from 1990 until 1999, when the word critical was removed and other changes were made to inspection report formatting; however, improper holding temperatures was one violation that did not change much in frequency following the change in inspection report format. The violation rate for each type of establishment studied—local, regional chain, national chain—was calculated by dividing the number of times the violation was cited by the number of inspections. The most frequently cited critical violations included food holding temperatures; the percentage of establishments with recurrent holding temperature violations was between 20-30% for all three establishment
categories in Oklahoma County, and an even higher range, between approximately 30% and 75%, in the Oklahoma State Department of Health (OCDH) jurisdiction, with the highest rate of recurrent holding temperature violations (around 75%) attributed to regional chains. The results revealed that regional chain restaurants in the OSDH jurisdictions had significantly higher critical violations and recurrent violations of some critical issues than the other two restaurant establishment categories, local restaurants and national chains. However, one issue noted was variability of citations based on inspector, with a significant difference in inspector citations for citations including holding temperature violations in counties under OSHD jurisdiction, although the variability in inspector citation of holding temperatures was not significant in Oklahoma County. The study’s authors concluded that despite inconsistencies in inspector citations, there were real differences in violation rates among the individual establishments studied (Phillips et al., 2006).

A 2002 study to identify characteristics of restaurants where foodborne incidents (FBIs) occur used data from the Los Angeles County (LAC) Environmental Health Management System (EHMIS) to obtain results of all routine inspections and data from reported foodborne incidences that triggered inspections, labeled as investigated foodborne incidents (IFBIs; Buchholz, Run, Kool, Fielding, & Mascola, 2002). Consumers experiencing gastrointestinal illness could contact the local health department, who would get a food history and determine if the foodborne illness was plausibly associated with the reported restaurant. Of these consumer complaints, about 40% triggered an inspection at the reported restaurant. At the time, Los Angeles County (LAC) had 23 geographic districts, about 21,000 restaurants, and 140 sanitarians. Inspection forms were based on the California Uniform Retail Food Facilities Law, and violations were divided into 10 categories, which comprised of several violations each. The category of food protection included violations such as incorrect food temperature, improper or incorrect food preparation, and improper thawing or refrigerating of thawed foods. In this retrospective cohort study of 10,267 LAC restaurants that underwent routine inspections from July to November of 1997, violations for both case restaurants (a restaurant with a routine inspection from July 1997 to November 1997 and a subsequent IFBI from July 1997 to June 1998) and non-case restaurants (no IFBI from July 1997 to June 1998) were assessed. During the study time period, 158 cases and 10,109 non-case restaurants were studied. Results revealed that case restaurants were more likely to be
large restaurants, and to have more violations for improper food storage, reuse of food, improper employee hygiene, lack of thermometers, and lack of maintenance or cleanliness of walls and ceilings. The median overall inspection score was lower in case vs. non-case restaurants, 86 and 88, respectively (p=0.01). One of the implications of the study was that food safety code violations are critical when examining prevention of foodborne illness; the study found that a “violation in the category of food protection,” which was controlled for both restaurant size and district, had an odds ratio of 1.7 (95% CI 1.2 to 2.4) of being associated with restaurants where foodborne incidents occurred that led to a special inspection by a sanitarian (Buchholz et al., 2002).

While inspections remain an integral part of food safety regulation, some studies have found a lack of evidence for associations between violations and foodborne illness, and have suggested that violations are not always accurate predictors of the incidence of foodborne infection. A study focusing on Miami-Dade County, Florida in 1995 tested the hypothesis that routine restaurant inspection violations predict foodborne outbreaks (Cruz et al., 2001). In 1995, the Florida Department of Business and Professional Regulation (DBPR) was responsible for conducting routine restaurant inspections for over 8,000 food establishments in the county, and each restaurant was required to be inspected 4 times a year. Twelve of the 57 items listed on the checklist, adapted from the 1976 federal food service sanitation manual, were defined as critical issues, and included factors relating to preparation, handling, and storage. A case restaurant was defined as one with a confirmed foodborne illness outbreak during the year, while a control restaurant had no confirmed foodborne illness outbreak within the year. Each case was matched with two randomly selected controls. 1995 had 187 reports of restaurant-associated foodborne illness, with 60 of those confirmed as cases. Results showed that of 12 (out of 57 total) critical violations, only the presence of vermin was associated with outbreaks, and close to half of case restaurants did not have citations for critical violations in the most recent inspection prior to the outbreak. Overall, cases and controls did not differ by violations cited in the inspection (Cruz et al., 2001).

A study focused on inspection data and scores from food establishments in Tennessee from 1993 to 2000 (Jones et al., 2004). Inspection data included all routine inspections, which were semiannual; inspection forms contained 44 items, including 13 critical items. Data for the study consisted of 167,574 restaurant inspections, with 29,008 unique
restaurants being examined. From the study period of 1993 to 2000, the mean inspection score increased by 3.6 points from 80.2, and the average number of violations per inspection decreased from 11.1 to 9.9. Of the 12 most common violations that were cited, none fell in the category of a critical violation. The most common critical violation cited was relating to storage or use of toxic items within the facility. For restaurants that were identified as linked to foodborne outbreaks in 1999-2002, the mean score of the most recent routine inspection prior to the occurrence of the outbreak was 81.2; however, this mean score was not significantly different from the mean scores of other restaurant inspections conducted. Moreover, restaurants associated with outbreaks and restaurants not associated with outbreaks did not differ significantly in the rank order of the most common violations cited during inspection. Mean scores of fast food restaurants, independent restaurants, and chain full-service restaurants were all similar, in the range of about 80-82. It was found that many restaurants with a final inspection score of greater than 90 had critical violations, while some restaurant with scores below 80 did not have any critical violations. It was concluded that no direct connections between restaurant score and likelihood of foodborne outbreaks can be confidently made, and other factors are important in assessing restaurant health safety (Jones et al., 2004).

Generally, studies studying the correlation between restaurant inspection score or violations and foodborne illness are few, in part because of the low numbers of epidemiologically confirmed and linked restaurant-associated outbreaks (Jones et al., 2004). Another major issue is the underreporting of foodborne illness (Jones et al., 2004).

**CLIMATE CHANGE**

Climate change is a long-term change in weather statistics including average temperatures and precipitation patterns within a given geographic location (National Oceanic and Atmospheric Administration [NOAA] & National Weather Service, 2007). The period of time beginning from the 1990s to the beginning of the 21st century has been the warmest period of time out of the global temperature records beginning in the mid 19th century (NOAA & National Weather Service, 2007). While large-scale climate changes have occurred in the history of the Earth as evidenced by geologic records, the current and future large-scale changes to climate have been evidenced to be attributed to anthropogenic
greenhouse gas concentrations (NOAA & National Weather Service, 2007). The large scale burning of fossil fuels increases the carbon dioxide in the atmosphere, which is at a record high from the past 650,000 years (NOAA & National Weather Service 2007).

The Southwest region of the US—including California, Nevada, New Mexico, Colorado, Utah, and Arizona—is known to be the hottest and driest in the nation (U.S. Environmental Protection Agency [EPA], 2016a). Approximately 90% of the 56 million people living in this region live in large cities including San Diego, Los Angeles, San Francisco, Las Vegas, Denver, Phoenix, Albuquerque; this the highest percentage of city dwellers of any region in the nation (EPA, 2016a). The population in this region is projected to increase by 68% by the middle of the century, and the people will undoubtedly see major changes occur that directly affect the land, water, agriculture, and health of the populations (Garfin et al., 2014) The Southwest has already seen substantial climate changes in recent decades; the most recent decade of 2001-2010 had record temperatures of nearly 2°F higher than any temperature averages recorded in the past 110 years (Garfin et al., 2014).

With the continued increase in global emissions, regional annual average temperatures are predicted to increase by 2.5°F to 5.5°F by 2041-2070, and increase by as high as 5.5°F to 9.5°F by the end of the century (Garfin et al., 2014). The greatest increases are projected to occur in the summer and fall months. Summer heat waves are expected to increase in duration and intensity. Even if global emissions are substantially reduced, projected increases of temperature by the end of the century are still expected to be alarmingly high—from 3.5°F to 5.5°F (Garfin et al., 2014).

According to the Third National Climate Assessment (from data sourced from NOAA), projections for average temperature increases on the hottest days for the end of the century (as compared to the turn of the century) reveal that the hottest days, which are so extreme they only occur once in 20 years, will increase by as much as 10 to 15 °F, assuming the emissions of heat trapping gases continue (Luber et al., 2014).

**SAN DIEGO CLIMATE PREDICTIONS**

According to the San Diego 2050 Report published by the San Diego Foundation, global temperatures are predicted to increase twice as fast in the next 40 years as they have in the past 40 years, with scientists hypothesizing that San Diego temperatures will surpass this...
trend for global temperature predictions (Alberts et al., n.d.). Average annual temperatures are expected to rise from 1.5°F to as high as 4.5°F (Young, Hedge, Brakke, & Thailing, 2008) Additionally, there are predictions that there will be more days of extreme high temperatures each year, with heat wave duration, frequency, and magnitude increasing as well (Alberts et al., n.d.; Young et al., 2008). There are predictions that the normally cold month of November will soon have climate conditions similar to those of September (Alberts et al., n.d.). Moreover, there are predictions that Miramar in San Diego will have temperatures exceeding 84°F for more than a third of the year (Young et al., 2008).

CLIMATE CHANGE AND PUBLIC HEALTH

Climate change affects human health by changing environmental factors including food, water, air, and weather that uniquely and collaboratively impact quality of life (EPA, 2016b) These changes will affect some people more seriously than others because of individual factors such as behavior, health status, age, gender, occupation, geographical location, economic status, and exposure, but will also affect people differently based on how well systems of public health management are established within their community (EPA, 2016b).

It is projected that warmer temperatures and the increased frequency and duration of heat days and heat waves in the US will increase heat-related deaths by as much as tens of thousands of additional deaths during the summer months each year by the end of the century. As urban areas are generally warmer than rural areas, changing climate conditions are projected to affect these areas more that the surrounding rural areas (EPA, 2016b). Increases in morbidity and mortality will be a direct effect from rising global temperatures and increasing extreme heat events (National Institute of Environmental Health Sciences [NIH], 2015). Extensive heat exposure can lead to heat exhaustion, heat cramps, heat stroke, and death, and particularly in vulnerable individuals (NIH, 2015). It can also worsen preexisting respiratory, cerebral, and cardiovascular conditions. Serious health effects from heat exposure disproportionately affect certain populations such as the elderly, children, the economically disadvantaged, and those with existing chronic conditions (NIH, 2015).

A project conducted by the CDC’s National Environmental Public Health Tracking (EPHT) Network and UC Berkeley researchers aimed to examine how areas with a heat
vulnerability index (HVI) are affected in terms of increased morbidity and mortality (Reid et al., 2012). The study compared morbidity and mortality rates on abnormally hot days and other days in various zip codes of 5 participating states: California, Massachusetts, New Mexico, Oregon, and Washington for the years 2000-2007, May through September. For each day in the study period, the deviation of the daily maximum temperature from each weather station’s historic daily normal maximum temperature was calculated. Deviant days were considered days where the deviation was in the upper 5th percentile of deviations at the particular station for the study period; extreme days were days in the upper 5th percentile of the absolute maximum temperature for the study period. Days on which maximum temperatures did not exceed 85°F were considered non-deviant or non-extreme. Results of the percentage of deviant days and extreme days in each month from May 1 through September 30, for the years 2001 through 2007 for 5 states found that California had 70,224 deviant days and 74,388 extreme days. For California, percentage of deviant days ranged from 6.1 to a high of 38.5 in May, and extreme days ranged from 5.8 to a high of 33.5 in July. For heat related illnesses in California, RR= .94 (95% CI 0.90-0.97) on non-deviant days, and RR=1.11 (CI 1.05-1.17) on deviant days (Reid et al., 2012).

A historic heat wave took place in July of 2006 in California, where it was estimated that an excess of 600 heat-related deaths may have occurred in the second half of July (Margolis, Gershunov, Kim, English, & Trent, 2008). A heat wave was defined as temperatures exceeding the 99th temperature percentile. During this time period from July 14th-July 30th, 19 counties, many of which were in the Central Valley, reported at least one death. Coroners identified 140 deaths due to hyperthermia; 126 were classified as classic heat-stroke, and 14 cases were classified as exertional heat stroke. Most of the deaths from classic heat stroke were older individuals who had at least one chronic health condition, thereby increasing the risk (Margolis et al., 2008).

California’s average temperature that July of 2006 surpassed the long-term average by 4°F (Edwards 2006 as cited in Knowlton et al., 2009). Following this 2006 heat wave event, the California Department of Public Health and the Natural Resources Defense Council initiated a study to gather information on hospitalizations and emergency department visits to gain more information on the reported illnesses exacerbated by the heat waves, which would help to assess intervention efforts aimed at decreasing heat-related morbidity.
and mortality (Knowlton et al., 2009). Results of the study found that during this 2006 heat wave, there were substantial increases in various morbidities throughout California, with an excess of approximately 16,200 emergency department (ED) visits and an excess of 1,200 hospitalizations, determined from the comparison of the count in the heat wave period to a non heat wave reference period (Knowlton et al., 2009). Diagnoses of the ED visits included heat-related illnesses, electrolyte imbalance, acute renal failure, nephritis, diabetes, and cardiovascular disease; diagnoses from hospitalizations were similar to those attributed to excess ED visits. For excess ED visits, significant increases were observed for all age ranges and for most race/ethnic groups; results for increased number of hospitalizations, and for increased number of hospitalizations within ages or ethnicities were not statistically significant (Knowlton et al., 2009). When assessing increased morbidity across California during the heat wave, patterns for 10 different causes were examined (Knowlton et al., 2009). For the cause of heat-related illness, it was found that RR=6.30 (95% CI, 5.67-7.01) for heat-related ED visits, and RR=10.15 (95% CI, 7.79-13.43) for heat-related hospitalizations. Results were statistically significant for heat-related illnesses for region (highest in Central Coast, RR=23.05 (95% CI, 15.05-37.10)), for age (highest for ≥65 years old, RR=10.87 (95% CI, 8.39-14.31)), and race/ethnicity (highest for Asian/Pacific Islander, RR=11.38 (95% CI, 5.53-27.14); Knowlton et al., 2009).

Climate changes including increases in the frequency, intensity, and duration of extreme heat events lead to issues such as drought, wildfires, and air pollution changes (Luber et al., 2014). As heat waves allow for periods of stagnant air, this contributes to increases in air pollution and decreased air quality, which can induce asthma and other adverse respiratory and cardiovascular health effects (EPA, 2016b). Projections include increases of ground-level ozone, indirect increases of particulate matter, increases in allergens, and other negative environmental factors that severely impact human health (EPA, 2016b).

Increasing air temperatures also means some vectors will be more active for longer periods of times, and will be able to potentially infect more animals and people (EPA, 2016b). Climate change will have an effect on temporal temperature changes, precipitation, and humidity, and will change the biology and ecology of vectors and intermediate agents responsible for propagating disease (Githeko, Lindsay, Confalonieri, & Patz, 2000). Certain
mosquito species including *Anopheles gambiae* complex, *Aedes aegypti*, *A. darling*, *A. funestus*, and *Culex quinquefasciatus*, which transmit a large majority of vector-borne diseases, are sensitive to changes in temperature throughout their life cycle. According to Rueda, Patel, Axtell, and Stinner (1990) and Gillies (1953), rising water temperatures facilitate larvae maturation, which means increased numbers of offspring (as cited in Githeko et al., 2000).

Water-related illnesses may also increase, as climate changes affect factors including changing water temperatures, heavy rains, run-off and flooding, and storms (EPA, 2016b). Water temperature increases will change timeframes of growth and the range of habitats of toxin-producing algae and species of *Vibrio* bacteria responsive for waterborne diseases (Trtanj et al., 2016). Waterborne diseases caused by exposure to bacteria, viruses, protozoa, and toxins in contaminated drinking water or recreational waters, or through consumption of certain seafood, are projected to increase (Trtanj et al., 2016).

**INDIRECT EFFECTS OF CLIMATE CHANGE ON FOOD SAFETY**

The idea that changes in weather patterns can directly or indirectly cause consequences including dust deposition and microbial contamination of leafy vegetables and herbs; the increase of vector transfer of human pathogens to vegetable crops; and the facilitation of increased rate of growth of microbes from higher temperatures, are all serious threats to public health (Akil, Ahmad, & Reddy, 2014). Rising temperatures may also affect some farming practices; animals may be transported to different areas or inside enclosed facilities to shield them from extreme heat exposure and stress, which may inadvertently lead to increased pathways of disease transmission (as cited in Tirado et al., 2010). A possible implication is that food crops or animal foods are more likely to be contaminated before they reach the retail food facility, further up the chain of farm to fork; thus, violations at the food facility means that control measures to prevent contamination and infections are insufficient or absent.

**TEMPERATURE AS A FOODBORNE ILLNESS RISK FACTOR**

Maintaining proper temperatures of potentially hazardous foods is crucial in reducing the growth of pathogenic bacteria that may be contaminating the food (OC Environmental
Health, n.d.). The number of bacteria ingested from contaminated food affects the progression of illness; ingesting a small amount of pathogenic bacteria may result in mild illness or may not result in an illness at all, while ingesting a large amount may cause severe illness in the individual. Improper holding temperatures of potentially hazardous foods allows pathogenic bacteria to rapidly reproduce to large numbers that are more likely to lead to foodborne illness. For potentially hazardous foods that must be kept at appropriate cold holding temperatures of below 41°F, walk-in coolers, prep coolers, cold top tables, holding food over ice, refrigerated displays, and refrigerated trucks are methods of achieving cold holding maintenance of foods. It is critical that the food itself be at a temperature of 41°F or below for the entire duration prior to serving and consumption. An issue may stem from repeated opening and closing of cooling equipment units that store the foods, which may cause an inadvertent increase in the temperature of the food. Hot holding of potentially hazardous foods should be maintained at a temperature of 135°F or above, temperature criteria outlined in the California Retail Food Code (CDPH, 2016). This is achieved through the use of steam tables, crock-pots, heat lamps, double boilers, and hot holding cases/cabinets. Food temperatures that fall in the range between 41°F and 135°F are considered to be in the danger zone, a critical temperature range that should be minimized for potentially hazardous foods (OC Environmental Health, n.d.).

Most bacterial pathogens that are responsible for foodborne illness proliferate at room temperature and even more rapidly at elevated temperatures; this suggests that future increases in ambient temperatures will have serious effects on the multiple steps within the food safety process of farm to fork (Tirado et al., 2010). Foods that are held in room temperature conditions have the increased risk of bacterial proliferation; the longer these foods are held outside the recommended guidelines, the more of a threat to health they become (Yeager et al., 2013). An additional factor noted by Yeager et al. (2013) was that some consumers do not immediately consume the food purchased at retail food facilities, which leads to an increased risk. According to the CDC, warm moist conditions and availability of nutrients can allow one bacterium that divides itself every 30 minutes to multiply to 17 million progeny in a span of 12 hours (CDC, 2015a).

Salmonella multiple more rapidly at high temperatures within the animal gut and within food, the optimal temperature for growth being 35-37°C (Akil et al., 2014). A major
cause of salmonella infection can be attributed to temperature violations during food storage and processing (Juneja et al., 2007). A study has also found that salmonella *enteritidis* is more associated with food transmission than salmonella *typhimurium* (Kovats et al., 2004).

According to the CDPH (2012) Salmonella Yearly Report Summary from 2011, incident cases of salmonellosis peaked during the months of July and August. The Campylobacteriosis Yearly Summary Report for 2012 showed similar findings of increased incidence during the months of July and August (CDPH, 2013). Such increases, however, are often attributed to seasonal social behavioral changes and activities, such as outside dining events, which are more prevalent during summer months.

**TIME AND TEMPERATURE REGULATIONS FOR RETAIL FOOD FACILITIES**

The FDA establishes a scientifically-based model food code to serve as a reference for ensuring safety within the retail food industry; while many jurisdictions have adopted this Food Code in part or in whole, it is not a federal law or regulation (FDA, 2013).

Food establishment inspections are implemented in order to ensure the safety of the public against foodborne illness. Inspectors rely on the scientifically based food code laws as the foundation for enforceable food safety regulations (FDA, 2015a). While traditionally inspections centered on sanitation, current inspections focus on the HAACP, Hazard Analysis and Critical Control Point, approach. Inspectors focus on those factors most often implicated as the cause of foodborne illness—sources of the food, storage methods, and preparation and post-preparation. Additional focuses include multi-ingredient food preparations, cooking of potentially hazardous foods, foods prepared in large volumes, foods prepared and held several hours before being served, and foods that require proper cooling or reheating. A food product’s temperature measurement is usually taken from its geometric center when measuring critical limits in cooking, cooling, and cold holding. Critical limits for hot holding also require measurements taken at points farthest from the heat sources, such as measurements taken near the product surface on steam tables. Ambient temperature measurements are additionally collected if there is a need to investigate suspected improper cooling practices or other potential hazards (FDA, 2015a). Section 3-501.16 of the FDA Food Code, “Time/Temperature Control for Safety Food, Hot and Cold Holding” states that:
(A) Except during preparation, cooking, or cooling, or when time is used as the public health control as specified under §3-501.19, and except as specified under (B) and in (C ) of this section, TIME/TEMPERATURE CONTROL FOR SAFETY FOOD shall be maintained:

(1) At 57°C (135°F) or above, except that roasts cooked to a temperature and for a time specified in 3-401.11(B) or reheated as specified in 3-403.11(E) may be held at a temperature of 54°C (130°F) or above; or

(2) At 5°C (41°F) or less.

(B) EGGS that have not been treated to destroy all viable Salmonellae shall be stored in refrigerated EQUIPMENT that maintains an ambient air temperature of 7°C (45°F) or less.

(C) TIME/TEMPERATURE CONTROL FOR SAFETY FOOD in a homogenous liquid form may be maintained outside of the temperature control requirements, as specified under (A) of this section, while contained within specially designed EQUIPMENT that complies with the design and construction requirements as specified under 4-204.13(E).

The Food Code also states that food temperature measuring devices should be provided and readily accessible (FDA, 2013). For “thin masses” such as meat patties and fish fillets, a temperature-measuring device with a small-diameter probe should be provided and accessible (FDA, 2013).

According to the County of San Diego Department of Environmental Health Food and Housing Division’s Retail Food Facility Operator’s Guide, time and temperature relationships as specified in proper hot and cold holding temperatures dictate that “potentially hazardous foods shall be held hot at 135°F or above or held cold at 41°F or below at all times…Potentially hazardous food items must be held inside properly functioning refrigeration units” (San Diego County, 2007). These potentially hazardous foods include meat, poultry, milk products, raw and cooked eggs, seafood, baked potatoes, and cooked rice (San Diego County, 2007).

Inspectors check temperatures of potentially hazardous food that require appropriate hot holding or cold holding temperatures during its transport to another location. If potentially hazardous food needs to be transported from the specified holding temperature to another location for preparation, the preparation must not exceed 2 cumulative hours without returning the food to the proper holding temperature (CDPH, 2016). Time is also a critical factor in holding temperature violations, and can be a major contributing factor to food hazards created (FDA, 2015a).
A hot and cold holding temperature violation, where “Multiple potentially hazardous foods or pooled eggs are held at temperatures of 50°F-130°F without any other intervention,” is considered one of the major violations that require immediate corrective action (San Diego County, 2007). According to the Guide, Permit Suspension may result if there are unsafe temperature controls of potentially hazardous foods (San Diego County, 2007).

**FOOD CONTAMINATION AND TEMPERATURE**

A study done to determine bacterial pathogens found on foods in two restaurants in Alabama—one usually receiving high inspections scores and the other low—revealed that certain foods were more likely to be out of compliance in terms of temperature guidelines (Yeager et al., 2013). Approximately 36% of the foods in both were found to have *Staphylococcus aureus*, and approximately 45% of the food samples obtained revealed those foods fell outside of the recommended temperatures (Yeager et al., 2013). Of the total hot foods sampled, only 70% (n=20) of chicken samples and 37.5% (n=8) of hamburger samples were delivered at the recommended temperature of greater than 135°F (Yeager et al., 2013). For cold foods such as chicken salad that should have been kept at the recommended temperature of less than 41°F, 60% of the samples (n=5) were found to be in compliance (Yeager et al., 2013).

**TEMPERATURE AND FOODBORNE ILLNESS**

Previous studies in different countries from the UK to Australia that have found strong positive associations between average ambient temperatures and cases of common foodborne diseases suggest that the increase in incidence in summer months may not be solely attributable to social behaviors and dietary decisions (Fleury, Charron, Holt, Allen, & Maarouf, 2006). A study conducted in two Canadian provinces, Alberta and Newfoundland-Labrador, investigated any associations between weekly cases of enteric bacterial disease and short-term ambient temperature variations (Fleury et al., 2006). While Alberta’s summers are mostly dry and warm, the summer weather of Newfoundland-Labrador is mostly moderate to cool wet. Cases of infection with *Salmonella*, *Campylobacter*, and entero-pathogenic *E. coli* were the focus of the study, and they were the most common reported bacterial enteric
pathogens at the time. Maximum, minimum, and average temperatures were obtained from over 90 stations in Alberta, and close to 60 stations in Newfoundland-Labrador. This study, analyzing data in the 9 year time period between 1992 and 2000, observed 6,282 cases of Salmonella, 1,743 cases of Campylobacter, and 9,664 cases of E.Coli from Alberta, and 986 cases of Salmonella and 1,188 cases of Campylobacter from Newfoundland-Labrador (Fleury et al., 2006). Confounding variables such as the effect of season, weekday, and holiday variation were controlled for, as well as cases clearly attributed to outbreaks. Results revealed weekly incidences of infection peaked in early summer months. Significant lag times between temperatures and incidence were found to be between 0 and 6 weeks. According to Hall, D’Souza, and Kirk (2002), temperature lags suggest the occurrence of contamination at steps in the food chain prior to preparation and point of consumption, including the processing plant or even farm (Fleury et al., 2006). Threshold models were used for each of pathogens studied; results showed an increase in relative risk with temperatures above the threshold for all pathogens studied, with 95% confidence intervals and narrow intervals. These threshold models assumed that temperature had no effect until the particular threshold temperature for each of the studied pathogens was reached, after which there was a linear relationship between temperature and cases. For the linear relationships after threshold temperatures, the slope was calculated as the log relative risk of disease per degree of temperature increase. The following threshold temperatures were used for Alberta: -10°C for Salmonella, -10°C for Campylobacter, and 0°C for E.Coli. In Alberta, it was found that for every degree increase in weekly temperature above the thresholds, the log relative risk for that agent increased by 1.2%, 2.2%, and 6%, respectively (Fleury et al., 2006). For Newfoundland-Labrador, with a Campylobacter threshold temperature of 0°C, it was found that for every degree increase in weekly temperature above this threshold, the log relative risk increased by 4.5%. However, lack of statistically significant associations between temperature and Salmonella cases in Newfoundland-Labrador were thought to be attributed to confounding variables (Fleury et al., 2006).

According to a recent article that sought to examine the relationship between climate effects and Salmonella infections, the authors used monthly data of Salmonella infections from the years 2002-2011 for three Southern states—Mississippi, Alabama, and Tennessee—in conjunction with meteorological data such as average air temperature and total
precipitation to quantify the hypothesized positive correlation (Akil et al., 2014). As Salmonella growth is optimized at higher temperatures, the optimal temperature for growth being 35°C -37°C, there is a higher bacterial load in the food supply in the summer months. According to Karl, Melillo, and Peterson (2009), average annual temperatures in the southern states have increased by approximately 2°F since 1970, and are projected to increase by 4-9°F in the latter part of the century (Akil et al., 2014). The study used SAS, a Mann-Kendall Test, and a Seasonal Trend test to quantify correlations between temperature and Salmonella cases (Akil et al., 2014). In the regression analysis, temperature and precipitation were the independent variables and Salmonella outbreaks was the dependent variable (Akil et al., 2014). The researchers also used Neural Network (NN) models, which are able to extrapolate and make “predictions” based on existing data—in this case, predictions based on future temperature trends. Results from the Mann-Kendall Test revealed that outbreaks were observed during the summer season, with peaks from July to September; the findings were statistically significant at p<0.01. Regression analysis performed from Mississippi data (R² =.554) and data from the three states (R²=.415) both revealed a statistically significant (p<0.01) positive correlation between temperature and Salmonella outbreaks. A significant finding revealed was that a 1°F increase in temperature will lead to a 4 case increase in Salmonella cases in Mississippi (Akil et al., 2014). Such results have implications on the serious public health impact in the case of future extreme weather events, and particularly heat events, in the US.

A study of ten European populations—Czech Republic, Denmark, England and Wales, Estonia, the Netherlands, Scotland, Slovak Republic, Poland, and Spain—aimed to determine how much of the variation in Salmonella cases on a weekly basis could be attributed to environmental temperature variations by using surveillance data from laboratory confirmed Salmonella cases from the respective populations (Kovats et al., 2004). The researchers used Poisson regression models adapted for time-series data, and controlled for inter annual variation in all regression models. Results revealed that for many of the countries, there was a linear association between temperature and salmonellosis cases, with some being linear after a threshold temperature value was reached. Most countries showed a peak in cases in late summer months, following the earlier peak in temperatures. There was an observed lag time of between 0-9 weeks between high temperatures and increased cases.
Approximately 35% of all salmonellosis cases in England and Wales, Poland, the Netherlands, Czech Republic, Switzerland, and Spain were found to be temperature-influenced (Kovats et al., 2004). For some countries studied, relationships were observed as being linear across all temperatures, and did not reveal a threshold. Estimates for slopes, a 5-10% increase in salmonellosis cases per 1°C, were noted as being similar to a study (D’Souza, Becker, Hall, & Moodie, 2004) of 5 Australian cities, where thresholds for salmonellosis in several cities were also not observed. Additionally, in the Australian study, incidence rate ratios with 95% confidence intervals for a 1°C increase in mean temperatures of the previous month on *Salmonella* notifications were found to be between 1.041 and 1.056 for all 5 cities studied. Moreover, Kovats et al. (2004) suggested that temperature effects were more associated with food preparation and handling than from non-food sources. Implications for the future regarding climate change center around average temperatures increasing, with more weeks with above-threshold temperatures expected to occur.

A related study used surveillance data from laboratory-confirmed *Campylobacter* cases from about 15 countries ranging from Denmark to New Zealand (Kovats et al., 2005). Various routes of transmission of *Campylobacter* include consumption of contaminated food, water, and milk products; recreational contact; and exposure to infected reservoir animals and birds. However, *Campylobacter* is not often implicated in common-sources outbreaks of food poisoning. For the countries studied, representative temperatures were chosen by analysis of daily temperature data from various stations within the regions. Surveillance data was converted to weekly frequencies of cases observed. Analysis included roughly plotting weekly cases with temperature variables, and also determining “peak” weeks for each year to try to access the timing of the increase in cases. Strong temperature effects on *Campylobacter* transmission were not found, and the effect of short-term increases in temperature were weak in comparison to the associations found in *Salmonella* transmission in the previous study (Kovats et al., 2005).

A study aimed at investigating the role of weather variability in gastrointestinal illness in Fukuoka, Japan in the years between 1999 and 2007 examined a total of 422,176 cases within the 9 year time period (Onozuka et al., 2010). The data source was the National Epidemiological Surveillance of Infectious Diseases system in Japan; the Japan Meteorological Agency provided the information for the weekly mean average temperatures
and relative humidity data. In Japan, infectious gastroenteritis is defined as having the symptoms of stomach pains, vomiting, and diarrhea. The study revealed a significant positive relationship between the relative risk of gastroenteritis cases and higher temperatures, considering a lag of 0-8 weeks, and after adjustments for seasonal, between-year, and humidity variations were made. Specifically, a significant temperature association was found for cases that observed lags of 3, 5, 6, and 7 weeks. This lag implies that temperature plays a role in pathogenic food contamination temporally earlier in the food production process. The most common infectious agents were determined to be norovirus, rotavirus, and *Escherichia coli*, with *E. Coli* infections peaking in the summer. Moreover, it was found that for a 1°C increase in temperature, infectious gastroenteritis cases increased by 7.7% (95% CI 4.6-10.8). If these findings can be applied to other regions, this would mean that a 1°C increase in temperatures worldwide would potentially mean an increase in millions of cases of infectious gastroenteritis (Onozuka et al., 2010).
CHAPTER 3

METHODS

TEMPERATURE DATA

Meteorological data was obtained from the NOAA. Daily temperature summaries—and specifically minimum and maximum daily temperature in tenths of degrees Celsius—were obtained for the study period January 1, 2013 to December 31, 2014 (NOAA, n.d.a). The station chosen to collect temperature data was the Montgomery Field airport station, chosen to be representative of San Diego weather for the study period observed. Montgomery Field station was most appropriate to represent daily temperature summaries in San Diego because of its relatively central location to multiple San Diego counties, and because temperature readings would be less likely to be skewed by proximity to the ocean and the sea breeze. NOAA was also used to access temperature data for historic average daily maximums in Celsius for the 30 year span between 1981-2010 (NOAA, n.d.b). These were imported as an additional variable into SPSS, to use as a source of comparison for the maximum daily temperatures for the observed 2-year study period. The difference between the maximum daily temperature for days in 2013-2014 and the historic maximum daily temperature for the specified 3-decade period were calculated to determine if days were unusually hot for the time of year.

INSPECTION DATA

Retail food facility routine inspection and violation data for the years 2013 to 2014 was obtained from San Diego County’s Environmental Health, Food and Housing Division. Data was presented as 4 excel files, inspection data and corresponding violation data for the years 2013 and 2014. Each inspection file listed the Record Name (facility name), Business Type, Record ID number (unique for each unique facility), Primary Address, Score, completed day of inspection, number of employees, and permit status. Each violation file
also included the specific violation(s) observed during inspection coded as Guide Item Text, and the violation category coded as Guide Item Status. There were 15 total different business types coded: caterer, licensed health care facility, minimal food preparation, miscellaneous food facility, mobile food facility commissary non-processing, mobile food facility commissary processing, non-profit food facility, pre-packaged retail market, restaurant food facility, retail food processing, retail market with deli, school processing food facility, school satellite food facility, vending machine commissary, and wholesale food warehouse.

The Food Inspection Report (Appendix A) as supplied by the County of San Diego, Department of Environmental Health, is a one-page document that is mostly formatted as a “check box” form. There are a total of 22 categories listed, with several violations listed for each. The 12 categories listed were divided into major violation observed, minor violation observed, and corrected onsite. These categories were: Demonstration of Knowledge, Employee Health & Hygienic Practices, Preventing Contamination by Hands, Time and Temperature Relationships, Protection from Contamination, Food from Approved Sources, Conformance with Approved Procedures, Consumer Advisory, Highly Susceptive Populations, Water/Hot Water, Liquid Waste Disposal, and Vermin. One violation in particular was isolated as the focal point of the study—“Proper hot & cold holding temperatures”—within the category of Time and Temperature Relationships. This violation had two additional check boxes, with “hot” or “cold.” This violation was able to be categorized as one of 3: major violation observed, minor violation observed, corrected onsite. For all facility types, all minor and major hot and cold holding temperature violations (total of 10,263), which were coded as numbers 7 (10,260) and *4a (3; caterer facilities only) on the inspection form and recorded in the inspection and violation data supplied by the County.

Violation categories that were listed in a separate section of the inspection form, where 1 point would be deducted from the total score if the violation was observed, included: Supervision, Personal Cleanliness, General Food Safety Requirements, Food Storage/Display/Service, Equipment/Utensils/Linens, Physical Facilities, Permanent Food Facilities, Sign Requirements, and Compliance & Enforcement.

Inspections were considered as unique events except in the case of retail markets, where a separate section of the facility, such as deli or a beverage stand, was treated as a separate inspection with its own unique inspection number.
Data Analysis

Data analysis was conducted using a combination of SPSS 23 and Microsoft Excel 2011. Violation and Inspection files in Excel as obtained by the County for each of the 2 years were separately converted into SPSS files. Both 2013 and 2014 inspection and violations files were merged to add “cases” by Record ID to combine the two data sheets for subsequent combined analysis. For analysis of violations and inspections for each business type, aggregates were separately calculated and descriptive statistics were run on frequencies, scores, inspections, and violations. Daily maximum and minimum temperature data for 2013-2014, in tenths of a degree Celsius, was exported as a .csv file and converted to Excel and SPSS 23 files. SPSS data sheets with inspection data for the two years merged were additionally merged to add “variable” by Completed Date to import the temperature data, converted to degrees Celsius. In regards to analyzing violations, all violations were recoded to isolate hot and cold holding temperatures, sorted by restaurant business type only, and were also recoded to differentiate between the various “Yes” violations that were considered significant: Impoundment, Closed immediately or Closed within 24 hour, and Facility Downgraded. Inspection counts and temperature violation counts were aggregated for each inspection day before a new variable was created for the rate of violations per inspection. After importing the historic average temperature maximum variable, another variable was created for the difference between daily maximums and the historic average daily maximums, to be further analyzed for significance in regards to violation rates.

The study focused specifically on the category of restaurant facilities because of its major role in foodborne illness as the source of contamination, and its ability to be potentially significantly affected by variations in temperature, in relation to hot and cold holding temperature violations. Restaurants serve a large number of consumers, and serve an assortment of potentially hazardous foods that may be implicated in foodborne illness cases.

The absence of consistent numbers of inspections per day was observed for the inspection data; to adjust for this variation, data was normalized to the hot and cold holding temperature violations per inspections. Statistical tests conducted included independent samples t-tests for various temperature cut-offs for maximum daily temperature, in relation to hot and cold holding temperatures violations per inspections observed. The same statistical test was used to assess violations per inspection for various values of temperature difference,
calculated as the difference between maximum temperatures observed in the 2 year period of 2013-2014 and the historical maximum temperatures for the 3 decade period between 1981-2010. Regression analysis was conducted to determine any significant relationships between the rate of violations and maximum temperature. Values of p<0.05 were considered significant.
CHAPTER 4

RESULTS

Table 1 shows a distribution of facilities, inspections, and total violations for the 15 different types of retail food facilities analyzed over the two year study period of 2013-2014. Some data including scores of facilities were missing, especially if the facility was ordered to be closed at inspection. A total of 3,872 scores were missing for 112,145 violations (3.5%), and 2,477 total scores were missing for 43,194 inspections (5.7%). Of 15,189 total unique facilities that were inspected, over half, 56.5%, of the facility types inspected were restaurant facilities. Other facility types inspected included retail market with deli, 10.0% (n=1525), pre-packaged retail markets, 8.8% (n=1337), and minimal food preparation facilities, 9.0% (n=1362). The number of inspections for each facility type was similar in proportion to the unique facility counts in each category of business types. The mean number of inspections per facility type ranged between 1.6 and 4.1 inspections, with the higher end of the range attributed to inspections of retail market with deli, school processing food facility, and school satellite food processing. For total number of any type of violations, 71.7% (n=80,413) were attributed to restaurant food facilities. The second highest number of violations were attributed to the category of retail market with deli (13.7%, n=15,344). Mean number of violations per business type, however, was highest for retail markets with deli, at 10.4; the second highest was for restaurant food facilities, at 9.5 violations. The total violations per inspection revealed the highest frequencies for the categories of restaurant food facility and retail market with deli, at 3.2 and 2.5, respectively. Calculations of violations per unique inspection within each business type found the highest frequency for restaurant food facilities, at 3.5 violations per unique inspection, and for retail market with deli, at 3 violations per unique inspection.
Table 1. Distribution of Facilities, Inspections, and Total Violations for 15 Retail Food Facility Business Type Categories, 2013-2014

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Facilities</th>
<th>Inspections</th>
<th>Violations</th>
<th>Total Violations per Total Inspections</th>
<th>Violations Per Unique Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (N%)</td>
<td>N (N%)</td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Caterer</td>
<td>264 (1.7%)</td>
<td>651 (1.5%)</td>
<td>2.5</td>
<td>1.1</td>
<td>841 (0.7%)</td>
</tr>
<tr>
<td>Licensed Health Care Facility</td>
<td>107 (0.7%)</td>
<td>301 (0.7%)</td>
<td>2.8</td>
<td>1.5</td>
<td>567 (0.5%)</td>
</tr>
<tr>
<td>Minimal Food Preparation</td>
<td>1362 (9.0%)</td>
<td>3341 (7.7%)</td>
<td>2.5</td>
<td>0.9</td>
<td>5525 (4.9%)</td>
</tr>
<tr>
<td>Miscellaneous Food Facility</td>
<td>825 (5.4%)</td>
<td>1574 (3.6%)</td>
<td>1.9</td>
<td>0.6</td>
<td>1194 (1.1%)</td>
</tr>
<tr>
<td>Mobile Food Facility Commissary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Processing</td>
<td>13 (0.1%)</td>
<td>21 (0.0%)</td>
<td>1.6</td>
<td>0.8</td>
<td>34 (0.0%)</td>
</tr>
<tr>
<td>Mobile Food Facility Commissary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td>29 (0.2%)</td>
<td>49 (0.1%)</td>
<td>1.7</td>
<td>0.7</td>
<td>89 (0.1%)</td>
</tr>
<tr>
<td>Non-Profit Food Facility</td>
<td>260 (1.7%)</td>
<td>653 (1.5%)</td>
<td>2.5</td>
<td>1.0</td>
<td>1156 (1.0%)</td>
</tr>
<tr>
<td>Pre-Packaged Retail Market</td>
<td>1337 (8.8%)</td>
<td>2495 (5.8%)</td>
<td>1.9</td>
<td>0.5</td>
<td>4029 (3.6%)</td>
</tr>
<tr>
<td>Restaurant Food Facility</td>
<td>8599 (56.5%)</td>
<td>24795 (57.4%)</td>
<td>2.9</td>
<td>1.1</td>
<td>80413 (71.7%)</td>
</tr>
<tr>
<td>Retail Food Processing</td>
<td>98 (0.6%)</td>
<td>264 (0.6%)</td>
<td>2.7</td>
<td>1.1</td>
<td>385 (0.3%)</td>
</tr>
<tr>
<td>Retail Market with Deli</td>
<td>1525 (10%)</td>
<td>6143 (14.2%)</td>
<td>4.0</td>
<td>3.1</td>
<td>15344 (13.7%)</td>
</tr>
<tr>
<td>School Processing Food Facility</td>
<td>255 (1.7%)</td>
<td>1055 (2.4%)</td>
<td>4.1</td>
<td>1.3</td>
<td>1084 (1.0%)</td>
</tr>
<tr>
<td>School Satellite Food Facility</td>
<td>404 (2.7%)</td>
<td>1618 (3.7%)</td>
<td>4.0</td>
<td>0.6</td>
<td>1212 (1.1%)</td>
</tr>
<tr>
<td>Vending Machine Commissary</td>
<td>3 (0.0%)</td>
<td>7 (0.0%)</td>
<td>2.3</td>
<td>0.6</td>
<td>10 (0.0%)</td>
</tr>
<tr>
<td>Wholesale Food Warehouse</td>
<td>108 (0.7%)</td>
<td>227 (0.5%)</td>
<td>2.1</td>
<td>0.6</td>
<td>262 (0.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>15189 (100%)</td>
<td>43194 (100%)</td>
<td>2.8</td>
<td>1.5</td>
<td>112145 (100%)</td>
</tr>
</tbody>
</table>

Table 2 lists descriptive statistics for the inspections scores within each business type. The range of scores for all business types was between 71 and 100, with a low of 71 associated with both restaurant food facility and retail market with deli. Minimum inspection scores in the 80s were found for the categories minimal food preparation, miscellaneous food facility, and pre-packaged retail market. Mean scores for all facilities ranged from 94 to 98, and median scores ranged from 94 to 99.
Table 2. Descriptive Statistics for Inspection Scores Within Each Business Type, 2013-2014

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>25% Percentile</th>
<th>75% Percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caterer</td>
<td>96</td>
<td>96</td>
<td>90</td>
<td>94</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Licensed Health Care Facility</td>
<td>96</td>
<td>96</td>
<td>90</td>
<td>94</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Minimal Food Preparation</td>
<td>96</td>
<td>96</td>
<td>85</td>
<td>94</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Miscellaneous Food Facility</td>
<td>97</td>
<td>97</td>
<td>86</td>
<td>96</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Mobile Food Facility Commissary</td>
<td>97</td>
<td>97</td>
<td>93</td>
<td>96</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>Non-Processing</td>
<td>96</td>
<td>96</td>
<td>93</td>
<td>95</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>Mobile Food Facility Commissary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td>95</td>
<td>96</td>
<td>90</td>
<td>94</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>Non-Profit Food Facility</td>
<td>95</td>
<td>96</td>
<td>90</td>
<td>94</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>Pre-Packaged Retail Market</td>
<td>95</td>
<td>94</td>
<td>80</td>
<td>94</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Restaurant Food Facility</td>
<td>94</td>
<td>94</td>
<td>71</td>
<td>91</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>Retail Food Processing</td>
<td>95</td>
<td>96</td>
<td>90</td>
<td>92</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>Retail Market with Deli</td>
<td>94</td>
<td>95</td>
<td>71</td>
<td>92</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>School Processing Food Facility</td>
<td>97</td>
<td>97</td>
<td>90</td>
<td>95</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>School Satellite Food Facility</td>
<td>97</td>
<td>97</td>
<td>90</td>
<td>96</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Vending Machine Commissary</td>
<td>97</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td>Wholesale Food Warehouse</td>
<td>98</td>
<td>99</td>
<td>97</td>
<td>98</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>94</td>
<td>94</td>
<td>71</td>
<td>92</td>
<td>96</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3 lists the various violations as coded by the San Diego County Department of Environmental Health, Food and Housing Division, by business type. All violations were separated into 4 categories: Out of Compliance, Out of Compliance-Minor, Out of Compliance-Major, and Yes. On the inspection form (Appendix A), the violations numbered between 1 and 23 were able to be marked as Minor violation observed (MIN OUT), Major violation observed (MAJ OUT), or Corrected Onsite (COS). Those violations that were corrected onsite were not included in the database. All the violations within the categories of Time and Temperature Relationships and Food From Approved Sources, as well as other critical violations, had the option of being a Major violation (a total of 18). Out of Compliance-Minor designations totaled 14 possible different violations.

Violations numbered 24 through 51 on the inspection form were coded as “Yes” on the inspection data. For violations that were observed in this category, a single point was deducted from the total score for each of the violations numbered 24 through 47. For violations 48 through 51, a notice was issued for noncompliances—these violations all dealt with Compliance & Enforcement. Of all the Yes categories, several significant violations
were isolated for Table 3: Impoundment, Closed immediately or Closed within 24 hour, and Facility Down-graded (combination of all facilities coded as downgraded to a B, downgraded to a C, or downgraded). Out of all the facilities inspected (43,194 total inspections), 189 were ordered to be closed immediately or within 24 hours; 168 of those were restaurants. 174 total restaurant facilities were down-graded one or more letter grade following inspection.

The temperature violation relating to hot and cold holding temperatures was isolated, as it was the focal point of this study. Out of a total of 10,263 hot and cold holding temperature violations that were observed (designated as 7 and *4a on the inspection form) for all facility types, 8,022 (78.2%) were attributed to restaurants. This count of 8,022 included all hot and cold holding violations that were marked as either Out of Compliance-Major (n=1,512, 18.8%) or Out of Compliance-Minor (n=6,510, 81.2%). A violation for this point meant a deduction of either 4 or 2 points from the total score.

Table 3. Violations* as Coded by the San Diego County Department of Environmental Health, Food and Housing Division, by Business Type 2013-2014

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Total Inspections</th>
<th>Hot &amp; Cold Holding Temperature</th>
<th>Out of Compliance Major</th>
<th>Out of Compliance Minor</th>
<th>Impoundment</th>
<th>Down-graded**</th>
<th>Closed Immediately/24hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caterer</td>
<td>651</td>
<td>18 (0.2%)</td>
<td>15 (0.3%)</td>
<td>2 (0.5%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Licensed Health Care Facility</td>
<td>301</td>
<td>60 (0.6%)</td>
<td>30 (0.7%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (0.5%)</td>
<td>5 (2.6%)</td>
</tr>
<tr>
<td>Minimal Food Preparation</td>
<td>3341</td>
<td>252 (2.5%)</td>
<td>73 (1.7%)</td>
<td>2231 (5.9%)</td>
<td>1 (0.5%)</td>
<td>5 (2.6%)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Food Facility</td>
<td>1574</td>
<td>17 (0.2%)</td>
<td>12 (0.3%)</td>
<td>603 (1.6%)</td>
<td>1 (0.2%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Mobile Food Facility</td>
<td>21</td>
<td>0 (0.0%)</td>
<td>16 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Commissary Non-Processing Mobile Food Facility</td>
<td>49</td>
<td>3 (0.0%)</td>
<td>60 (0.1%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Commissary Processing</td>
<td>653</td>
<td>75 (0.7%)</td>
<td>27 (0.6%)</td>
<td>429 (1.1%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Non-Profit Food Facility</td>
<td>2495</td>
<td>163 (1.6%)</td>
<td>59 (1.4%)</td>
<td>1711 (4.5%)</td>
<td>8 (1.8%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Pre-Packedaged Retail Market</td>
<td>24795</td>
<td>8022 (78.2%)</td>
<td>3536 (81.0%)</td>
<td>25818 (68.2%)</td>
<td>344 (78.0%)</td>
<td>174 (92.6%)</td>
<td>168 (88.9%)</td>
</tr>
<tr>
<td>Restaurant Food Facility</td>
<td>24795</td>
<td>49778 (73.1%)</td>
<td>25818 (68.2%)</td>
<td>344 (78.0%)</td>
<td>174 (92.6%)</td>
<td>168 (88.9%)</td>
<td></td>
</tr>
<tr>
<td>Retail Food Processing</td>
<td>264</td>
<td>230 (0.3%)</td>
<td>15 (0.3%)</td>
<td>133 (0.4%)</td>
<td>3 (0.7%)</td>
<td>0 (0.0%)</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>School Process Food Facility</td>
<td>1055</td>
<td>167 (1.6%)</td>
<td>47 (1.1%)</td>
<td>418 (1.1%)</td>
<td>2 (0.5%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>School Satellite Food Facility</td>
<td>1618</td>
<td>592 (0.9%)</td>
<td>40 (0.9%)</td>
<td>574 (1.5%)</td>
<td>1 (0.2%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Vending Machine Commissary</td>
<td>7</td>
<td>7 (0.0%)</td>
<td>0 (0.0%)</td>
<td>3 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Wholesale Food Warehouse</td>
<td>227</td>
<td>219 (0.3%)</td>
<td>6 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>43194</td>
<td>10263 (100%)</td>
<td>68050 (100%)</td>
<td>4364 (100%)</td>
<td>37840 (100%)</td>
<td>441 (100%)</td>
<td>188 (100%)</td>
</tr>
</tbody>
</table>

*Violations coded by San Diego County Department of Environmental Health, Food and Housing Division
**Facility coded as down-graded, down-graded to a B, or down-graded to a C

RESTAURANT FOOD FACILITY

For restaurant facilities only, total inspections numbered 24,795, with a mean of 44 and a median of 45 inspections per day, and a standard deviation of 24.2. The maximum number of inspections that took place in a day for the years 2013-2014 was 103. Hot and cold holding violations for 2013-2014 totaled 8,022, with a mean of 14.6 and a median of 15
violations per day. The maximum number of hot and cold holding violations per day reached 39. For the temperature data for the time period observed—a total of 563 days—the mean maximum daily temperature was 23.6 °C, and median 23.3 °C; the minimum and maximum of the daily maximum temperatures were 10.6 °C and 39.4 °C, respectively.

Data was collected for a total of 563 days for the two year period from January 1, 2013 to December 31, 2015. This included only days on which inspections occurred, whether or not any violations were observed. A total of 24,795 restaurant facility inspections were conducted in that time period, out of a total of 43,194 total inspections for all retail food facility categories.

**Figure 1** shows a distribution of daily temperature maximums in degree Celsius for the period of time between January 1, 2013 to December 31, 2014, for days on which inspections occurred (a total of 563 days).

![Figure 1. Distribution of daily maximum temperatures (°C), 2013-2014.](image-url)
Substantial fluctuations in temperature data were found for days temporally close to each other, in every month and season. While temperatures trends within the study time period showed general increases in temperatures for the months of June, July, August, September, and October for both years studied, many outliers were observed, especially in the direction of higher temperatures.

**Figure 2** shows raw inspection counts for a total of 563 days for the two years studied (out of a total of 700 days); days where inspections did not occur were not included in the data analyzed.

![Graph showing inspection counts](image)

**Figure 2. Inspection counts, 2013-2014.**

Mean, median, and standard deviation number of inspections per day was 44, 45, and 24.2, respectively. The minimum number of inspections conducted per day was 1, and the maximum was 103. A total of 24,795 restaurant facility inspections were conducted between
January 1, 2013 and December 31, 2014. The distribution of days on which inspections occurred was not systematic. Also, inspections still occurred on non-business days and some national holidays. Since inspection counts were greatly varied, data was normalized to the hot and cold holding temperature violations per inspection.

**Figure 3** shows the normalized value of restaurant-associated hot and cold holding temperatures violations per inspections graphed over the two year period of 2013-2014 for days that had at least 1 inspection. There appears to be a small increase in hot/cold holding violations in the summer months.

**Figure 3. Restaurant- associated hot and cold holding temperature violations per inspection, 2013-2014.**

**Figures 4 and 5** show restaurant-associated temperature violations vs. the inspection dates on which they were observed, averaged for weeks 1 to 52 for the combined 2 year period of 2013-2014. Lines x=23 and x=35 denote the approximate window of the months
June, July, and August to better show the summer season. **Figure 5** shows the violations vs. inspection dates for those days that had 5 or more inspections.

**Figure 4.** Restaurant-associated temperature holding violations per inspection by weeks, 2013-2014.

**Figure 5.** Restaurant-associated temperature holding violations per inspection by weeks, 2013-2014 (adjusted for days with at least 5 inspections).
Figure 6 shows restaurant-associated hot and cold holding temperature violations per inspection for 2013-2014 vs. daily maximum temperatures for all days in which there was at least 1 inspection (563 days), whether or not a temperature violation occurred. The correlation is weakly positive, at $r=0.167$ ($p<0.001$). The slope is .005, a small positive relationship.

Figure 6. Restaurant-associated temperature holding violations per inspection vs. daily maximum temperatures, 2013-2014.

Figure 7 is the adjusted graph of restaurant-associated temperature violations per inspection vs. daily temperature maximum, with the data points removed for those days on which less than 5 inspections occurred, for a total of 496 days. Correlation is slightly higher at $r=0.286$, ($p<0.001$), with a similar slope of .005 (temperature violation per inspection per increase in degree Celsius).
Figure 7. Restaurant-associated temperature holding violations per inspection vs. daily maximum temperatures, 2013-2014 (adjusted for days with at least 5 inspections).

In Figure 8, daily maximum temperature in °C for the years 2013-2014 is graphed with the average historical maximum temperature for that particular day, calculated as an average daily temperature maximum from the time period between 1981-2010, and retrieved from NOAA.
Figure 8. Daily maximum temperatures (2013-2014) and average historical maximum temperatures (1981-2010) per inspection date.

It appears that daily temperature maximums for 2013-2014 exceed the historically recorded average maximum temperatures from 1981-2010 more than they fall below the historic maximum temperatures, denoting numerous days that were unusually hot for the study period.

Figure 9 shows the calculations of the difference between daily maximum temperatures °C on dates in 2013-2014 and the historic average maximum daily temperatures for those days for the 3-decade period from 1981 to 2010. The equation y= 0 is graphed to better show a distribution for days in which the maximum daily temperatures in 2013-2014 exceeded historic daily maximum temperatures.
Out of a total of 563 days that had inspections, 333 days had a positive difference, meaning the particular day’s maximum temperature exceeded the average historical maximum temperature for the day. Alternatively, 230 days had a negative value for the difference in temperature, meaning that the daily maximum temperature was less than the recorded average historical maximum temperature for that day.

Table 4 Results of independent sample $t$-tests for 4 cutpoints of absolute temperature ($20^\circ$C, $25^\circ$C, $30^\circ$C, $35^\circ$C ) and for 5 values of difference (-2.5, 0, 2.5, 5, 7.5) between maximum temperature within the study period of 2013-2014 and historical average temperature maximums for the 3 decade period of 1981-2010.
Table 4. Descriptive Statistics for Inspection Scores Within Each Business Type, 2013-2014

<table>
<thead>
<tr>
<th>Absolute Maximum Temperature</th>
<th>n (days)</th>
<th>≥ cutpoint</th>
<th>% of Total</th>
<th>Mean Violations/Inspection above cutpoint</th>
<th>Mean Violations/Inspection below cutpoint</th>
<th>Equal Variances Not Assumed p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>437</td>
<td>20°C</td>
<td>77.6%</td>
<td>0.31</td>
<td>0.27</td>
<td>0.009</td>
</tr>
<tr>
<td>25°C</td>
<td>220</td>
<td>39.1%</td>
<td>0.33</td>
<td>0.29</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>61</td>
<td>10.8%</td>
<td>0.34</td>
<td>0.30</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>35°C</td>
<td>11</td>
<td>2.0%</td>
<td>0.35</td>
<td>0.30</td>
<td>0.199</td>
<td></td>
</tr>
</tbody>
</table>

Difference between Daily Temperature Maximum and Average Historical Temperature Maximum (excluding summer months June, July, Aug)

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ -2.5</th>
<th>85.1%</th>
<th>0.31</th>
<th>0.28</th>
<th>0.14</th>
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<tbody>
<tr>
<td>479</td>
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<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 0</th>
<th>59.1%</th>
<th>0.31</th>
<th>0.29</th>
<th>0.115</th>
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<tbody>
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<td>333</td>
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<table>
<thead>
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<th>n (days)</th>
<th>≥ 2.5</th>
<th>31.4%</th>
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</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 5</th>
<th>18.1%</th>
<th>0.31</th>
<th>0.30</th>
<th>0.942</th>
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<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 7.5</th>
<th>8.9%</th>
<th>0.30</th>
<th>0.31</th>
<th>0.736</th>
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<tr>
<td>50</td>
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</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ -2.5</th>
<th>84.2%</th>
<th>0.29</th>
<th>0.28</th>
<th>0.622</th>
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<tbody>
<tr>
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<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 0</th>
<th>60.2%</th>
<th>0.30</th>
<th>0.28</th>
<th>0.194</th>
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<table>
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<th>n (days)</th>
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<th>35.7%</th>
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<table>
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<th>n (days)</th>
<th>≥ 5</th>
<th>22.1%</th>
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<th>0.655</th>
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<th>n (days)</th>
<th>≥ 7.5</th>
<th>12.0%</th>
<th>0.30</th>
<th>0.29</th>
<th>0.584</th>
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</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ -2.5</th>
<th>82.5%</th>
<th>0.27</th>
<th>0.29</th>
<th>0.291</th>
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</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 0</th>
<th>60.2%</th>
<th>0.27</th>
<th>0.27</th>
<th>0.95</th>
</tr>
</thead>
<tbody>
<tr>
<td>165</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 2.5</th>
<th>36.5%</th>
<th>0.27</th>
<th>0.27</th>
<th>0.757</th>
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<tbody>
<tr>
<td>100</td>
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</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 5</th>
<th>23.0%</th>
<th>0.26</th>
<th>0.27</th>
<th>0.545</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>n (days)</th>
<th>≥ 7.5</th>
<th>10.6%</th>
<th>0.27</th>
<th>0.27</th>
<th>0.922</th>
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</thead>
<tbody>
<tr>
<td>29</td>
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</table>

Seasonal Analysis*

<table>
<thead>
<tr>
<th>n (days)</th>
<th>146</th>
<th>25.9%</th>
<th>0.35</th>
<th>0.29</th>
<th>&lt;0.001</th>
</tr>
</thead>
</table>

Note: *Comparison of violation frequency between summer months (June, July, August) and remaining 9 months

Independent sample t-tests for comparison of means revealed that absolute temperature cut-offs of 20°C, 25°C, 30°C were statistically significant for temperature violations per inspection (p<.05).

Results of the sample t-tests were not significant for any of the differences between the daily maximum temperature and the historic average maximum tested: -2.5, 0, 2.5, 5, or 7.5.

Seasonal analysis was conducted by calculating rates of holding temperature violations per inspection for summer months for the total 2 year study period, and comparing it with the violation rates for the remaining months; mean violation rates were 0.35 and 0.29, respectively. Of the total days on which an inspection occurred, 146 were days within the summer months of June, July, and August. The results were shown to be statistically significant, at p<0.05.
CHAPTER 5

DISCUSSION

We present here the first study of the potential relationship between increases in ambient temperatures and subsequent increases in frequency of cold holding temperature violations in retail restaurant facilities. Previous studies focusing on temperature effects on food safety have shown some trends suggesting that increases in ambient temperatures precede increases in cases of foodborne illness in the regions studied. While the relationship supports the concept of increased microbial proliferation at increased temperatures optimal for microorganisms, the link between ambient temperatures, cold holding temperature violations, and increased cases of illness have not been studied. Analysis of routine food facility inspections for the study period of January 1, 2013- December 31, 2014 obtained from the San Diego County Department of Environmental Health demonstrated that both absolute increases in maximum temperature over 20°C, 25°C, 30°C and also summer season were associated with a significant increase in the rate of temperature violations detected. In addition, a significant positive slope of 0.005 between these rates and maximum temperatures was observed.

Analysis of the data for facility inspections and violations for the two year study period of 2013-2014 revealed that restaurants accounted for over half of the nearly 15,200 unique facilities inspected within that time period, and a total of 24,795 inspections occurred for restaurant facilities. As studies such as Angulo and Jones (2006) and Gould et al. (2013) have found that over 50% of foodborne outbreaks were attributed to restaurants, violations in restaurants are critical to examine when exploring methods of controlling foodborne illness, as both inspection scores and rates of critical violations have been found to be predictors of outbreaks (Buchholz et al., 2002; Irwin et al., 1989). Irwin et al. (1989) compared inspection scores to likeliness of outbreak occurrence and found that case restaurants had a significantly lower average inspection score than control restaurants, with scores of 83.8 and 90.9,
respectively. Restaurants with a score of 86 points or less were approximately 5 times more likely to have had an outbreak than those with scores above 86. Restaurants with violations relating to compromised food practices such as improper temperature controls of potentially hazardous foods, improper storage and handling of equipment, and other critical violations had a significantly increased risk of an outbreak (Irwin et al., 1989). Buchholz et al. (2002) compared violation rates between case restaurants, or restaurants with routine inspections and subsequent investigated foodborne illness incidents, to those of control restaurants. The study found that case restaurants were more associated with violations related to various issues including improper food storage, improper employee hygiene, lack of thermometers, and inadequate sanitation. The median overall inspection score was lower in case vs. non-case restaurants, 86 and 88, respectively (p=0.01; Buchholz et al., 2002). From analysis of restaurant-associated foodborne illness outbreaks as reported by FoodNet, Gould et al. (2013) found that proliferation factors such as inadequate cold holding temperatures contributed to approximately 25% of a total of 458 outbreaks examined, and that inadequate time and temperature controls were associated with outbreaks of *E. Coli 0157* (100%), *C. perfringens* (81%), and *Salmonella* (58%).

The rate of hot and cold holding temperature violations per inspection averaged approximately between 0.2 and 0.4 per day in this study. Phillips et al. (2006), in studying violation rates and inspection frequency in various regions in Oklahoma, found that the “holding temperature violation” had a rate of 0.139 (n=48, p<0.001) in the High Risk category in OCCHD (Oklahoma City-County Health Department) and approximately 0.186 (n=37, p<0.01) in the high risk category in OSDH (Oklahoma State Department of Health).

In this analysis, the effect of summer season (June, July and August for the two year period studied) was linked to an increase in the rate of temperature violations found per routine inspection (0.35 vs. 0.29, p<0.001). This increase may relate to an increase in foodborne illness during the summer months, as has been found in some previous studies. Akil et al. (2014) found peaks in *Salmonella* outbreaks in months July to September (p<0.01) in three Southern states from 2002-2011. Regression analysis additionally revealed statistically significant positive correlations between temperature and *Salmonella* outbreaks (Akil et al., 2014). Vrbova et al. (2012) found that domestic cases of campylobacteriosis, cryptosporidiosis, giardiasis, salmonellosis, and VTEC-illness in Ontario, Canada showed
peaks in incidence of diseases in the summer months of July and August. Another Canadian study, Fleury et al. (2006), found that weekly incidences of enteric bacterial disease peaked in early summer months, with significant lag times between temperatures and incidence ranging between 0 and 6 weeks. A study in Fukuoka, Japan revealed a significant positive relationship between the relative risk of higher temperatures and gastroenteritis cases, considering a lag of 0-8 weeks; *E. Coli* infections were shown to peak in the summer (Onozuka et al., 2010). Some of the increase in summer months has been attributed to outdoor food events such as barbeques, where cooking food thoroughly is a concern, but these findings may point to a potential role of restaurants in these increases. If the significant seasonal effect on the rate of temperature violations holds true in repeat studies, the importance of an increase of inspections in the summer season should be evaluated by the local body responsible for conducting inspections.

Regression analysis of temperature violations per inspection vs temperature found that every degree Celsius increase in temperature was associated with approximately 0.005 temperature violations per inspection. Absolute increases over various temperature cutpoints were assessed in this study and specifically, temperatures of 20°C, 25°C, 30°C, 35 °C. Independent samples t-tests for various cut-points of absolute maximum temperatures found significant relationships for the temperatures of 20°C (p=0.009), 25°C (p<0.001), and 30°C (p=0.032) in regards to rate of temperature violations. In other studies, temperature thresholds for various pathogenic agents were studied. Fleury et al. (2006) used threshold models for the specific pathogens studied; these threshold models assumed that temperatures had an effect—and particularly a linear relationship between temperature and cases—after the threshold for each pathogen was reached. Threshold temperatures for Alberta, Canada were -10 °C for *Salmonella*, -10 °C for *Campylobacter*, and 0 °C for *E.Coli*; for every degree increase in weekly temperature above the thresholds, the log relative risk for that agent increased by 1.2%, 2.2%, and 6%, respectively. Newfoundland-Labrador, Canada had a *Campylobacter* threshold temperature of 0°C, where it was found that for every degree increase in weekly temperature above this threshold, the log relative risk increased by 4.5% (Fleury et al., 2006) In comparison to San Diego, average daily temperatures indicate that many days are above-threshold days, indicating an increased risk from pathogenic agents. A study of 10 European populations also suggested a linear relationship between temperature
and *Salmonella* cases after a country-specific threshold temperature that ranged between -2°C and 15°C was reached (Kovats et al., 2005). Most countries showed a peak in cases in late summer months, following the earlier peak in temperatures, with lags of between 0 and 9 weeks. There was also found to be an increase in salmonellosis cases for every 1°C increase in weekly temperature above 5 degrees Celsius. About one third of salmonellosis cases in 7 European populations were found to be temperature-influenced (Kovats et al., 2005). Onozuka et al. (2010) found that for a 1°C increase in temperature, infectious gastroenteritis cases increased by 7.7% (95% CI 4.6-10.8). If these findings can be applied to other regions, this would mean that a 1°C increase in temperatures worldwide would potentially mean an increase in millions of cases of infectious gastroenteritis (Onozuka et al., 2010).

As San Diego is a region that sees extreme hot weather in both the summer and also the winter months, an analysis was conducted to determine whether any of San Diego’s unusually high temperatures throughout the two year span of 2013-2014, as compared to the historical average maximum temperatures for the region for the 3 decade period of 1980-2010, were associated with a higher rate of temperature violations; differences of -2.5, 0, 2.5, 5, 7.5 between maximum temperatures within the study period and the historical average temperature maximums were assessed, but were not found to be statistically significant. Historic average temperature maximums were obtained from the Montgomery Field Station. Seeking to investigate how a region’s heat vulnerability index is associated with increased rates of morbidity and mortality, Reid et al. (2012) observed rates on abnormally hot days and other days in 5 states in the 8 year period from 2000-2007, examining specifically the months May through September. Similarly, the deviation of the daily maximum temperature from each weather station’s historic daily normal maximum temperature was calculated. Deviant days, or days where the deviation was in the upper 5th percentile of deviations at the particular station for the study period, was examined. Extreme days were days in the upper 5th percentile of the absolute maximum temperature for the study period. The relative risk of heat-related illnesses was examined for deviant and non-deviant days. This methodology of assessing possible associations between temperature and the variable of interest in the study, heat-related illness, could have been also applied to determine associations with increased rates of temperature violations by comparing daily maximum temperatures to historic average maximum temperatures for the region.
In comparison to previous studies centering on inspection scores and violations as potential predictors of foodborne illness, this study’s average inspection scores were surprisingly high, ranging between 94 and 98 for all of the 15 business types studied. In comparison, a 1989 study (Irwin et al., 1989) in Seattle King County, Washington found average inspection scores of 83.8 for case restaurants and 90.9 for control restaurants, while a 2002 study (Buchholz et al., 2002) focusing on Los Angeles County found median overall inspection scores of case restaurants to be 86 and controls to be 88. Investigating factors behind the high inspection scores in San Diego County can be a future point of study.

While only routine inspections were analyzed in this study, poor inspection results should lead to follow up inspections or even permit suspension (Irwin et al., 1989). Proper educational and regulatory action should be taken to ensure that the threat of foodborne illness is prevented (Irwin et al., 1989). Thorough education regarding the risks associated with specific violations may be a helpful tool to provide the employees and management of food facilities receiving poor inspection scores on many violations (Irwin et al., 1989).

Increased surveillance can improve detection of foodborne cases (Jones et al., 2004). Proper surveillance of foodborne illness, and further investigations of any complaints of foodborne illness, will provide better data to address questions of food safety within restaurant facilities (Irwin et al., 1989).

Due to the fact that inspections are now a part of mandatory food safety regulation across America, there can be no true controls that can serve as comparison to assess the effectiveness of inspections in preventing the propagation of disease (Jones et al., 2004).

Prevention efforts aimed at minimizing the occurrence of critical temperature violations in retail food facilities can address several factors, including placing greater weight on holding temperature violations in regards to the point value deduced from the total score, and also focusing on addressing repeat violators. Facilities with repeat temperature violations should be followed up with more diligently, especially if the percentages of establishments with repeat violations remains high. A study in Oklahoma that looked an inspection data from 1996-2000 found that the percentage of establishments with recurrent holding temperature violations was between 20-30% for all three establishment categories (local, regional chain, national chain) in Oklahoma County, and an even higher range, between approximately 30% and 75%, in the Oklahoma State Department of Health (OCDH).
jurisdiction, with the highest rate of recurrent holding temperature violations (around 75%) attributed to regional chains (Phillips et al., 2006). The results of the study revealed that regional chain restaurants in the OSDH jurisdictions had significantly higher critical violations and recurrent violations of some critical issues than the other two restaurant establishment categories, local restaurants and national chains (Phillips et al., 2006). Further studies looking at the distribution of the types of restaurants (local, regional, national) and their respective violation rates can provide better insight into which areas should be targeted for corrective actions. Future studies can also look to conduct analysis by additional factors such as the size of the restaurant facility and regional location within the County, and seek to determine if those factors are additionally related to patterns or increases in violation rates. Additional studies may take an in depth analysis at the specific contributors of the significant associations found in the study. Future studies can expand the time frame of study for a larger period of time than the two years observed, and can look at other large cities such as Los Angeles County as a source of comparison.

To expand the scope of the study, future studies can integrate an additional variable as a source of comparison—foodborne illness cases. Epidemiological data on foodborne infections such as salmonellosis or campylobacteriosis confirmed to be linked to a specific retail food entity can be included if the information is available from a valid data collection source.

**LIMITATIONS**

One major limitation of this study is that although there are separate sections to indicate “cold” or “hot” holding temperature violations on the inspection form, differentiated as two separate “check” boxes, the final data set was not translated in this manner, and only listed the holding temperature violation as the combined “hot and cold holding temperature violation.” The inability to separate hot holding and cold holding violations did not allow for more direct measurement of possible associations between increased temperature and cold holding temperature violations, the factor of interest in the study. The percent of the overall violations that are cold holding is unknown, though could be determined from a manual review of the inspection sheets.
Possible explanations for the increased rates of violations include the fact that the summer months may be commercially busier, especially in tourist towns like San Diego, which can put a strain on the food safety maintenance, especially if those units used to keep food at the appropriate temperatures are continuously being used during high traffic windows (e.g. the constant opening and closing of refrigeration units by various employees due to large customer volume at peaks in service).

A major limitation in regards to accurately capturing the maximum temperatures for the study period was the use of a single station, Montgomery Field, to correspond with temperatures at all of the various facilities studied, as temperatures can vary greatly across regions and the station’s reading is not guaranteed to reflect the most accurate temperature at the restaurant facility at the time.

Another limitation to the study was inconsistencies in coding, including naming of the individual facilities and naming of the individual violations and their respective grouping categories. Inconsistencies in categorization and labeling created a challenge in separating unique data, as some of the same violations were coded in different numbers and/or different text when referring to the same factor of interest; minor differences such as using “and” instead of “&” might have created separations where there should have been overlaps. Some facilities also had missing data including missing overall inspection scores.

In reference to the specific data collected from the inspections, some studies (Irwin et al., 1989; Phillips et al., 2006) noted that there is variability of inspection results based on the subjectivity of the different inspectors. Other factors noted that affect scoring including demographics of the inspectors and time since last standardized training (Jones et al., 2004).

Suggestions to improve data collection and coding for the County of San Diego include creating uniform violation nomenclature for unique violations, ensuring that unique facility names are standardized, and using separate violations for cold and hot holding temperature violations.

**CONCLUSION**

Food facility inspections remain an integral component of food safety management, and are overseen and facilitated by the local government. They provide a glimpse of food manufacturing practices and methods within various types of retail food facilities. However,
the extent to which the outcome of inspections, in regards to the types of violations observed, are predictive of the onset of foodborne illness is still being evaluated. This study aimed to identify any relationships between the variable of maximum daily temperature and cold holding temperature violations, as temperature violations have been observed as being a precursor to foodborne illness, a serious concern in a nation where restaurants play a large role in consumer culture. Changing environmental conditions can potentially threaten the food safety maintenance of retail restaurants, and can potentially allow for increases in violations that directly impact the health of consumers. Rapidly increasing temperatures in the coming decades due to climate change, as is consistently projected, might mean controls in restaurant facilities are under strain to maintain safe temperatures for potentially hazardous foods. Upon examining routine inspection results for the 2 year period of time between January 1, 2013 and December, 21 2014, seasonal analysis revealed a statistically significant difference between the rate of hot and cold holding temperature violations per inspection in the summer months of June, July, and August, and the remaining 9 months of the year. Results also demonstrated that absolute increases in maximum temperature over 20°C, 25°C, and 30°C were associated with a significant increase in the rate of temperature violations detected. In addition, a significant positive slope of 0.005 between these rates and maximum temperatures was observed. Such results suggest that increased temperatures have an effect on critical temperature violations, where potentially hazardous foods kept in conditions outside of safe temperature zones may more readily become the agents of pathogenic exposure for consumers. This study had several limitations, including an inability to determine whether the coded temperature violations were hot or cold holding violations, and inconsistent coding of data. While more studies should be conducted to further investigate this hypothesis, this study suggests that future efforts should be focused on increased surveillance and better monitoring of food-handling practices that prevent the propagation of diseases attributed to exposure from food in various retail food facility settings affected by the changing state of the environment.
REFERENCES


environmental public health tracking study. *Environmental Health Perspectives, 120*(5), 715-720. doi:10.1289/ehp.1103766


APPENDIX A

FOOD INSPECTION REPORT
APPENDIX B

SAN DIEGO COUNTY OF ENVIRONMENTAL
HEALTH, FOOD AND HOUSING DIVISION DATA
VARIABLE HEADINGS OF ROUTINE
INSPECTION AND VIOLATION DATA 2013-2014

CT
RECORD ID
RECORD NAME
PRIMARY ADDRESS
BUSINESS TYPE
NUMBER OF EMPLOYEES
STATUS
INSPECTION NUMBER
COMPLETED DATE
INSPECTION TYPE
INSPECTION STATUS
SCORE
GUIDE ITEM TEXT
GUIDE ITEM STATUS