

**The relationship between warm season  
temperatures and heatwaves on the  
incidence of *Salmonella* and  
*Campylobacter* cases in  
Adelaide, South Australia**

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Master of Public Health

**A thesis submitted in fulfilment of the requirements  
for the degree of Doctor of Philosophy**

**July 2017**

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# Declaration

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# Abstract

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## Background

*Salmonella* and *Campylobacter* spp. are the most common foodborne disease pathogens reported worldwide. Changes in climate observed through increasing warmer ambient temperature and heatwaves are considered to be contributing factors to the emergence and re-emergence of foodborne diseases. Warmer ambient temperature enhances the survival of pathogens in the environment, leading to increased contamination of food and water directly impacting on human health when resulting in diarrhoeal illness. Indirectly, social and behavioural factors may also have an impact on foodborne disease as a consequence of climate change. Warmer weather may bring about a change in people's eating behaviour, food preferences, and behaviour related to unsafe food practices potentially increasing the risk of foodborne illness. However, evidence concerning the effects of warmer temperature and heatwaves on *Salmonella* and *Campylobacter* infection is still relatively scarce, and little is known about human behaviour related to food safety practices in response to warmer weather.

## Aim

This thesis is divided into four studies each with specific aims. In broad terms, these were: study 1) to assess food safety practices, food shopping preferences and eating behaviours of people diagnosed with *Salmonella* or *Campylobacter* infection and resident of South Australia in the warm season months (January to March 2013), and to identify if socioeconomic status is associated with their behaviour and practices; study 2) to examine the relationship between warmer ambient temperature and the incidence of *Salmonella* and serotypes; study 3) to examine the relationship between heatwaves and the incidence of *Salmonella* and serotypes; and study 4) to examine the relationship between warmer

ambient temperature, and heatwaves and the incidence of *Campylobacter* infection in Adelaide, capital city of South Australia from 1990 to 2012. An overall aim was to provide scientific evidence for public health policy making and practical guideline development for foodborne disease control and prevention in the context of climate change.

## **Methods**

Disease notification data for all studies were obtained from the South Australian state's health department notifiable disease surveillance system. Climate data for studies 2 to 4 were sourced from the Bureau of Meteorology.

Logistic regression was the analytic approach used in study 1, a cross-sectional survey using a questionnaire to examine knowledge, behaviour and perceptions related to food safety. In addition, information about behaviour and preferences related to shopping and dining out, consumption of foods on warm days, preferences for receiving food safety information on warm days and perceived probability of heat as a risk factor for infectious gastroenteritis was also collected. Time-series analysis was the overarching framework used in the analyses for studies 2 through 4 to quantify the effects of temperature and heatwaves on *Salmonella* disease notifications (overall and the five common serotypes), and *Campylobacter* disease notifications in the warm season months (October to March). Specific approaches within these studies included Poisson regression analysis with Generalized Estimating Equations and Distributed Lag Non-Linear Models.



## Results

In study 1, *Salmonella* and *Campylobacter* cases generally engaged in unsafe personal and food hygiene practices. Participants had poor knowledge of food safety and they were not aware of high-risk foods associated with an increased risk of foodborne illness. Survey responses specifically related to warm weather found that certain food safety practices, and participants' eating behaviours and food preferences were influenced by temperature, but that generally socioeconomic status did not influence food safety practices.

In study 2, daily *Salmonella* notifications were positively associated with temperature, such that cases increased by 1.3% per 1°C rise in temperature in the warm season.

However, greater increases in incidence of *Salmonella* notifications were observed among specific serotypes and phage types. A temperature threshold of 38°C was detected at which notifications for certain *Salmonella* phage types increased in Adelaide.

In study 3, heatwave intensity had a significant effect on daily counts of overall salmonellosis with a 34% increase in risk of infection. Specific *Salmonella* serotypes and phage types were sensitive to the effects of heatwaves. Further, the effects of temperature during heatwaves on the number of *Salmonella* cases and serotypes were found at lags of up to 14 days.

In study 4, there was little evidence of an increase in risk of *Campylobacter* cases associated with either temperature or heatwaves in the warm seasons. During a heatwave, *Campylobacter* notifications decreased by 19% within a temperature range of 39-40.9°C.

## **Conclusion**

This thesis presents the first detailed examination of the effects of warm season temperature and heatwaves on *Salmonella* and *Campylobacter* notifications. Furthermore, this is the first research reported to assess the effects of ambient temperature and heatwaves on *Salmonella* serotypes and their phage types. Overall, these findings demonstrate an increased incidence of *Salmonella* notifications in the warm seasons associated with higher temperature, and more pronounced effects during heatwaves. The findings have also highlighted that human behaviour and food safety practices are influenced by temperature in the warm season months.

These results provide important evidence for policy makers and stakeholders to develop and recommend early warning systems about foodborne disease prevention during heatwaves. In addition, the results highlight the need for targeted public health interventions at a household and population-level in raising awareness and providing education about the importance of food safety in warmer weather.

## Publications contributing to this thesis

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Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Factors influencing knowledge, food safety practices and food preferences during warm weather of *Salmonella* and *Campylobacter* cases in South Australia. *Foodborne Pathogens and Disease*. 2017;14(3):125-131.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effect of temperature on different *Salmonella* serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia. *Epidemiology and Infection*. 2016;144(6):1231-1240.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Heatwaves differentially affect risk of *Salmonella* serotypes. *Journal of Infection*. 2016;73(3):231-240.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effects of ambient temperature and heatwaves on daily *Campylobacter* cases in Adelaide, Australia, 1990–2012. *Epidemiology and Infection*. 2017;145(12):2603-2610.

## Conference presentations arising from this thesis

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Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

29<sup>th</sup> Annual Scientific Conference of the International Society for Environmental Epidemiology: Healthy places, healthy people – where are the connections?  
Sydney, Australia, September 2017.

**Oral presentation:** The effect of warm season temperature on *Salmonella* serotypes and phage types.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

20<sup>th</sup> International Epidemiological Association World Congress of Epidemiology Conference: Global epidemiology in a changing environment: The circumpolar perspective, Anchorage, Alaska, August 2014.

**Oral presentation:** Food safety during hot weather: knowledge and practices of *Salmonella* and *Campylobacter* cases in South Australia.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

26<sup>th</sup> Annual Scientific Conference of the International Society for Environmental Epidemiology Conference: From Local to Global: Advancing Science for Policy in Environmental Health, Seattle, Washington, August 2014.

**Oral presentation:** The relationship between heatwaves and the incidence of *Salmonella* infection in a temperate climate.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

National Climate Change Adaptation Research Facility Conference: Climate Adaptation 2013: Knowledge + Partnerships, Sydney, June 2013.

**Speed talk and poster presentation:** Food safety practices and knowledge during heatwaves: A survey of *Salmonella* and *Campylobacter* cases.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

The University of Adelaide, Faculty of Health Sciences Postgraduate Research Conference, Adelaide, September 2013.

**Poster presentation:** Food safety knowledge and practices on hot days: Results from a pilot study of *Salmonella* and *Campylobacter* cases.

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P.

The University of Adelaide School of Population Health Seminar Series, Adelaide, February 2013.

**Oral presentation:** The relationship between heatwaves and the incidence of foodborne illness in a temperate city.

# Acknowledgements

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My heartfelt thanks to my supervisory panel – Professor Peng Bi, Associate Professor Lynne Giles, Professor Janet Hiller, Associate Professor Ann Koehler and Dr Ying Zhang. I am very lucky to have wonderful supervisors each with their unique academic and research expertise that has guided me throughout this long process. Without their constant encouragement, belief in me and support, I would have found this journey very difficult.

I would like to thank staff from the Disease Surveillance Investigation Section, Communicable Disease Control Branch, Department for Health and Ageing (SA Health) for their support and help with my research.

Thank you to the participants for taking time to complete the food safety survey, without their contribution study 1 would not have been possible.

To the staff in the School of Public Health for their support throughout my candidature and for taking an interest in my work, providing support and much encouragement with lovely chats along the way.

A thank you to my family and friends for supporting me in my study and for understanding why I was not always available.

To my patient and wonderful husband – Scott for taking care of things when I was otherwise occupied with my study, and to my amazing children – Lily and Ella for putting up a “Do not disturb” sign on my study door and knowing when to give me the space to work on my PhD on weekends.

# Abbreviations

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BOM	Bureau of Meteorology
CDCB	Communicable Disease Control Branch
CI	Confidence Interval
DALY	Disability Adjusted Life Years
(°C)	Degree Celsius
DLNM	Distributed Lag Non-Linear Model
ENSO	El Nino-Southern Oscillation
GEE	Generalized Estimating Equations
GLM	Generalized Linear Model
IPCC	Intergovernmental Panel on Climate Change
IRR	Incidence Rate Ratio
OR	Odds Ratio
NSW	New South Wales
NZ	New Zealand
RR	Relative Risk
SA	South Australia
UK	United Kingdom
USA	United States of America

# Chapter 1 Introduction

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## 1.1 Background

Warmer temperatures and extreme weather events such as heatwaves, are becoming more frequent, placing a greater burden on the health of populations. Mortality and morbidity burden related to heatwave exposure is well documented [1-5] as is the impact of temperature on the incidence of infectious diseases specifically related to vector-borne and gastrointestinal disease [6-8]. However, evidence concerning the effects of warmer temperature and heatwaves on foodborne disease is relatively scarce, despite projections that the burden of gastrointestinal disease will increase if average global temperatures continue to rise. The most recent assessment by the Intergovernmental Panel on Climate Change (IPCC) also reports that foodborne and waterborne diseases are likely to increase as a consequence of warmer temperature [9].

Foodborne disease contributes significantly to the global burden of infectious diseases and is comparable to other major infectious diseases such as malaria and tuberculosis [10]. *Salmonella* and *Campylobacter* spp. are the most frequently reported causes of foodborne disease worldwide, and place a significant burden on human health. Compared to other diarrhoeal causing pathogens, *Salmonella* spp. are responsible for more deaths from foodborne disease, and infection from *Campylobacter* and *Salmonella* spp. account for 1-4 million Disability Adjusted Life Years (DALY) worldwide [10]. In Australia, similar trends have been reported, with infection from *Salmonella* (54.1 DALY per 1000 cases per year) and *Campylobacter* (23.5 DALY per 1000 cases per year) accounting for a large proportion of burden of illness on human health [11]. In South Australia (SA), the burden of foodborne disease is significant as rates for *Salmonella* and *Campylobacter* notifications in 2011 were higher than in other Australian states and territories [12].



Some foodborne diseases are highly sensitive to climate variability [8]. High ambient temperature provides an ideal environment for pathogens to thrive, proliferating with rising water and air temperatures [13]. The last 50 years has seen an increase in frequency, intensity and duration of extreme high temperatures, with heatwaves becoming more frequent [9]. This has also been the experience for Adelaide, the capital city of SA and the location for the studies undertaken for this thesis. Adelaide has a temperate, or Mediterranean climate, with mild winters and hot, dry summers favouring ideal temperatures for pathogen growth, leading to potential risk of foodborne infection. The annual average number of days above 35 degrees Celsius (°C) is 17 days; by 2030 this is estimated to increase to 21-26 days [14].

Temperature plays an important role in infectious disease transmission patterns either directly by influencing pathogen growth and survival, particularly in higher temperatures, or indirectly via affecting people's behaviour and practices. Behavioural and social factors influenced by weather and temperature can also influence occurrence of foodborne illness [15]. People's eating behaviours and preferences for certain types of foods may change according to the weather and climate seasons. Inadequate food safety practices in warm weather may also contribute to increased cases of infectious gastroenteritis. However, little is known about human behaviour in response to warmer weather, and if changes in people's eating behaviours, food preferences and food safety practices during warmer weather increase the risk of foodborne disease. Generally, consumers do not take necessary measures to safeguard against the transfer of pathogens during food preparation, potentially increasing the likelihood of cross-contamination in the domestic kitchen which may lead to foodborne illness [16]. Lack of food safety practices in the warm weather may lead to even more cases of foodborne disease.

Previous studies have reported a positive association between temperature and *Salmonella* infections, but the evidence for the direction and strength of a relationship between

*Campylobacter* infections and temperature is less clear. There is little evidence available concerning the impact of warmer temperature on *Salmonella* and *Campylobacter* infections as few studies have examined this in relation to temperature occurring in the warm seasons (typically summer). As well, there is scant evidence concerning the effects of heatwaves on the number of *Salmonella* and *Campylobacter* cases. Very few studies have examined whether heatwaves affect the risk of infection with certain *Salmonella* serotypes, and no studies have reported the relationship of temperature or heatwaves with *Salmonella* phage types. Addressing these gaps in knowledge may help inform targeted intervention strategies for prevention of foodborne disease.

## **1.2 Thesis aim**

As elaborated on more fully at the end of the literature review in Chapter 2, the primary aims of this thesis were twofold. The first aim was to explore if human behaviour and practices related to food safety were influenced by warmer weather or socioeconomic status (study 1). The second aim was to examine the effects of warmer ambient temperature and heatwaves on *Salmonella* infections including serotypes and phage types, and on *Campylobacter* infections (studies 2 to 4). With rising ambient temperatures predicted, coupled with longer, more intense and frequent heatwaves, the potential for increases in *Salmonella* and *Campylobacter* infection incidence is significant, placing an even higher burden on human health. Therefore, it is critical to gain an understanding of the mechanisms of the role of high temperatures and heatwaves on transmission of *Salmonella* and *Campylobacter* spp. and to inform policy makers and stakeholders with the evidence base for safe food preparation practices. In addition, the findings from this thesis will contribute information for targeted health promotion initiatives at a population-level in order to reduce the incidence and burden associated with foodborne disease due to high temperature.

### **1.3 Thesis outline**

The thesis is the format of a PhD by publication comprising eight chapters. Following this brief introduction outlining the rationale and aims of the study, Chapter 2 provides a comprehensive literature review on the major aspects of this study, i.e. the behavioural and social factors that could influence the occurrence of foodborne infection in the warm seasons, and a synthesis of the epidemiological studies that have examined the effects of temperature and heatwaves on *Salmonella* and *Campylobacter* infection. Chapter 3 outlines the methodological framework and the analytical approach used to address each of the specific research questions of this thesis. The subsequent chapters represent the main body of work, consisting of four distinct but related studies that addressed the research questions. Studies 1 to 4 (Chapters 4, 5, 6 and 7) have been published in peer-reviewed journals. Chapter 4 explores the factors influencing knowledge, food safety practices, food shopping preferences and eating behaviours of people diagnosed with *Salmonella* or *Campylobacter* infection in the warm season. In Chapter 5, the relationship between warmer ambient temperature and the incidence of *Salmonella* serotypes and phage types is examined. Further to this, Chapter 6 presents results concerning the relationship between heatwaves and the incidence of *Salmonella* serotypes and phage types. Chapter 7 examines the relationship between warmer ambient temperature and heatwaves and the incidence of *Campylobacter* infection. Finally, in Chapter 8, the discussion and conclusion bring together the results from the four studies, with consideration given to areas requiring future research.

## Chapter 2 Literature review

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This chapter provides background information about the effects of temperature and heatwaves on risk of infection by *Salmonella* and *Campylobacter*. There are two main parts to this literature review. The first part relates to the social and behavioural factors that may influence the occurrence of foodborne infection in the warm season. The second part provides an epidemiological review of published studies that have examined the effects of ambient temperature and heatwaves on foodborne disease, with specific reference to *Salmonella* and *Campylobacter* infections.

This chapter is structured as follows. First, a brief summary is given in Section 2.1 of the impact of climate change on weather variability as predicted with rises in ambient temperature, and increased frequency, intensity and duration of heatwaves, especially in southern Australia. In Section 2.2, an overview is presented of the burden of foodborne disease worldwide, with particular emphasis on *Salmonella* and its serotypes, and *Campylobacter* spp. in Australia. A brief description of the signs and symptoms of the infections, reservoir, routes of transmission, and temperature range for bacterial growth follows. In Section 2.3, food safety practices, people's eating behaviours, and high-risk foods for *Salmonella* and *Campylobacter* spp. that may have an influence on increased notifications in the warm season are outlined. A comprehensive overview of available studies, internationally and in Australia, concerning the effects of temperature and heatwaves on *Salmonella* and *Campylobacter* notifications is discussed in Section 2.4 through 2.8. Finally, research gaps are identified in Section 2.9 confirming the need to examine the relationship between ambient temperature and foodborne disease so as to inform the development of policy and recommendations for the prevention of foodborne illness during warm seasons and heatwaves in the context of climate change.

## **2.1 Changing climate**

### **2.1.1 Warm season temperature and heatwaves**

A recent assessment by the IPCC reports that the global mean surface temperature has increased since the beginning of the 20<sup>th</sup> century, with the first decade of the 21<sup>st</sup> century recording the warmest temperature [17]. Moreover, the last 50 years has seen an increase in frequency, intensity and duration of extreme temperatures. Cooler days and nights have become less frequent, and hot days and hot nights have increased, such that heatwaves are also likely to become more frequent in Europe, Asia and Australia [18].

Australia has experienced an increase in mean daily temperature by 0.9°C since 1910, with projected increases in the annual average temperature of 0.6-1.3°C from 2020 to 2030 [19]. These projections, based on different emission scenarios, are compared to the annual average temperatures recorded from 1986 to 2005. An analysis of heatwave trends in Australia from 1950 to 2005 concluded that eastern Australia and southern Australia experienced significant increases in heatwave occurrences compared to other regions in Australia [20].

SA has a temperate climate that is characterised by hot dry summers with mild winters, and of all the capital cities in Australia, Adelaide is the driest, with little rainfall during the summer months. The average ambient temperature in SA increased by 0.96°C in the last 95 years, a larger increase than observed nationally [21]. The number of days each year above 35°C in Adelaide is expected to increase by 50% by 2090, while the number of days per year where temperatures over 40°C are reported is predicted to double in this time [19].

## 2.2 Foodborne disease

Increases in ambient temperature have a substantial effect on the burden of infectious diseases as such diseases are influenced by weather conditions, with some following a seasonal pattern suggestive of a possible association with climate change [6, 22]. Warmer weather can drive the emergence, re-emergence and transmission of infectious diseases, as it is well established that survival and multiplication of pathogenic microorganisms in the environment and in food are influenced by high temperatures [23, 24]. Warmer summer temperatures enhance the survival of microorganisms in host animals and in the environment, leading to increased contamination of food and water, and thus an increase in the incidence of foodborne infection worldwide [25]. Furthermore, human behaviour in response to warmer weather, such as changes in people's eating behaviours, food preferences and food safety practices in the warm season may also increase the risk of foodborne disease.

Foodborne diseases are infectious or toxic in nature, and occur through the ingestion of contaminated food or water which results in mild to serious gastrointestinal illness in humans [26]. Annually 2.8 billion cases of gastrointestinal diseases are estimated to be reported worldwide [27]. In Australia, with a current population of more than 24 million, the incidence of infectious gastroenteritis attributed to foodborne disease in 2010 was estimated to be 4.1 million cases per year [28].

*Campylobacter* and *Salmonella* spp. are common causes of foodborne illness in humans and are the two most frequently reported bacterial aetiological agents worldwide [10]. In Australia, *Campylobacter* and *Salmonella* infection incidences increased between 2000 and 2010, and these were the leading causes of hospitalisation related to gastroenteritis [28]. In 2010, of the 550 million infectious gastroenteritis cases reported in the world, 96 million were attributed to *Campylobacter* spp. The proportion of cases attributed to foodborne transmission in Australia in 2010 for *Campylobacter* spp. was estimated as 77% [29]. In

Australia, *Campylobacter* spp. had the greatest burden for DALYs [11]. Annually between 1,700-2,000 *Campylobacter* cases are reported in SA, and in 2014, *Campylobacter* notifications accounted for 52% of all notified gastrointestinal infections to the SA Communicable Disease Control Branch (CDCB) [30].

An estimated 93.8 million *Salmonella* cases per year are reported globally, of which 80.3 million are foodborne [10, 27]. The proportion of *Salmonella* infections attributed to foodborne transmission in Australia was estimated as 72% in 2010 [29]. In fact, the incidence of *Salmonella* infection has increased significantly in Australia since 2000 [31]. Salmonellosis accounts for a large proportion of the burden of illness in humans and in 2010 the highest fatality rate attributed to gastroenteritis in Australia was for *Salmonella* infection. Annually, around 600-1,000 *Salmonella* cases are reported in SA, and in 2014, *Salmonella* notifications in SA accounted for 35% of all notified gastrointestinal infections to the CDCB [30].

Foodborne illness represents a significant cost to the Australian community. The annual cost of foodborne illness in Australia, based on 2002 and 2004 prices, was approximately \$1.25 billion. Productivity and lifestyle costs were estimated at \$771.6 million (62% of the total), followed by premature mortality at a cost of \$231.5 million. Associated health care costs accounted for \$221.9 million [32]. Based on the estimate that one third of gastroenteritis cases are foodborne infections, the cost per case of health services and surveillance is estimated to be close to \$40. However, the real cost is likely to be higher, given that only one in seven cases is notified; a cost of \$280 per notification case appears more reasonable [33]. In both estimates a greater proportion of the cost is attributed to health services rather than surveillance and disease control [33]. Recent estimates indicate that gastroenteritis-related illness accounts for 13 million missed paid work days per year in Australia [34]. Illness from *Salmonella* infection is estimated at 0.4 days per case, or 2.8

days per case if we account for under-reporting of the number of work days lost to illness [33]. This places an immense economic burden on society in terms of loss of productivity.

### **2.2.1 *Salmonella* infection**

Salmonellosis is an infectious gastrointestinal illness, caused by the bacteria *Salmonella* spp. Symptoms of non-typhoidal salmonellosis in humans are diarrhoea, nausea, mild fever, abdominal cramps and vomiting, with an incubation period of eight to 72 hours (usually 24–48 hours). Mortality associated with *Salmonella* infection is rare in Australia; however a small number of cases can develop bacteraemia, arthritis, meningitis or pneumonia following infection [35]. Salmonellae have an optimal temperature range for growth of 35-43°C, making temperature conditions associated with heatwaves ideal for enhancing growth in food and water sources. Salmonellae can be found in the intestinal tracts of domestic and wild animals. Asymptomatic animals shed salmonellae in their faeces, leading to contamination of the environment including soil, crops, plants and water sources [35]. Transmission to humans occurs via the faecal-oral route through the consumption of contaminated food or water or via contact with infected animals [35].

#### *Salmonella serotypes and phage types*

There are over 2,500 *Salmonella* serotypes [36] (also referred to as serovars), and 300 phage types identified [37]. In Australia, the distribution of *Salmonella* serotypes varies between geographical regions. Not all types cause human disease as some are host adapted to certain animal species [35]. The six serotypes phage typed in Australia are Bovismorbificans, Enteritidis, Hadar, Heidelberg, Typhimurium and Virchow [38]. *Salmonella* Typhimurium is the most commonly notified serovar in Australia [31], with a broad host range capable of infecting animals and humans [35]. A study in Australia identified five different pathways that have the potential to transmit infection and cause illness. These include foodborne, zoonotic, human-to-human, waterborne and environmental such as through direct contact with soil, water and air [29]. For example, in



Tasmania, Australia, *Salmonella* Mississippi is endemic, and it has been suggested that transmission is associated with environmental exposure [23].

### **2.2.2 *Campylobacter* infection**

Campylobacteriosis is an infectious gastrointestinal illness caused by the bacteria *Campylobacter* spp. Symptoms in humans include diarrhoea, nausea, abdominal pain, and fever, with an incubation period of 18 hours to eight days (usually three days). Mortality associated with *Campylobacter* infection is rare; however infection has been associated with reactive arthritis and with Guillain-Barré syndrome, a condition involving muscle weakness [35].

Growth of the bacteria occurs within a temperature range of 30-45°C. *Campylobacter* does not proliferate at temperatures <30°C, and hence does not multiply in foods kept at usual room temperatures [39]. *Campylobacter* are ubiquitous in the environment and hosts include wild domestic animals and birds. They can be found in the gastrointestinal tract of cattle, sheep, goats, dogs, rabbits, cats, chickens, turkey, duck and pigs [35]. Flies can also carry the bacteria and transmit them to humans [40]. Transmission to humans occurs via the faecal-oral route through the consumption of contaminated food or water or via contact with infected animals.

This section has highlighted the burden associated with human infection from foodborne disease, and in particular from *Salmonella* and *Campylobacter* spp. the focus of this thesis. The fact that pathogens proliferate in warm ambient temperatures thus contaminating food and water leading to an increase in gastrointestinal illness illustrates the direct effect of climate change on infectious diseases, adding evidence to the significance of foodborne disease as a public health problem. There are also indirect effects of climate change on foodborne disease related to changes in people's behaviour, and food safety practices that have the potential to contribute to an increase in disease incidence. There is a gap in

knowledge concerning changes to people's behaviour and food safety practices that could be influenced by weather, and which led to the first study in this thesis - a survey of food safety practices of people diagnosed with *Salmonella* and *Campylobacter*. Social and behavioural factors influencing food safety practices and preferences in warm weather will be discussed briefly in the next section.

### **2.3 Social and behavioural factors influencing food safety practices and preferences in warm weather**

This section focuses on the literature concerning food safety underpinning the development, analysis and interpretation of the survey for study 1 (presented in Chapter 4). The key questions in the survey related to knowledge and behaviour in safe food handling practices, preferences for shopping and eating out, and consumption of high-risk foods for *Salmonella* or *Campylobacter* infection. In addition, preferences for receiving food safety information on warm days and perceived probability of heat as a risk factor for infectious gastroenteritis were also collected. The literature specific to food safety behaviours and practices related to warm weather and seasons is virtually non-existent, thus this section briefly draws on previous studies related to food safety in general. *Salmonella* and *Campylobacter* show seasonal variation in prevalence that may relate to effects of primary production, food processing and/or food handling by consumers [23]. Inadequate food preparation practices and lack of food safety knowledge of consumers may be responsible for foodborne disease from food consumed in the home [41].

### **2.3.1 Food safety practices**

Previous community survey studies in Australia [26, 42, 43] and internationally [44-46] have found gaps in food safety knowledge and practices in households. Poor practices in food preparation and hygiene suggest that, in general, consumers do not take necessary measures to safeguard against the transfer of pathogens during food preparation. This potentially increases the likelihood of cross-contamination in the domestic kitchen leading to foodborne illness [16]. This can become more problematic if poor food safety practices are undertaken in the warm seasons, as the potential to contaminate food during handling and preparation is one possible mechanism through which higher temperatures can increase the risk of foodborne disease. Climate change with increasing temperature and prolonged heatwaves may contribute to food safety hazards through direct (effect of warm temperature on pathogen multiplication leading to food/water contamination) or indirect impacts, such as changes in consumer behaviour [47]. Generally, food safety practices in warm weather may be linked to risky consumer behaviour such as the time taken to unpack cold food and place in storage. A New Zealand (NZ) study found that only a small proportion of respondents carried their food in an insulated bag, although that study did not relate practices according to ambient temperature [44]. Defrosting frozen food at room temperature in the warmer weather is also considered risky behaviour. Previous studies found that consumers defrosted food at room temperature for extended periods of time [45, 46, 48]. This practice may contribute to foodborne illness since multiplication of microorganisms in food is directly influenced by ambient temperature [47].

Another unsafe practice is storage of food in refrigerators that are not maintained at the correct temperature. Knowledge on correct refrigerator temperature has found to be poor, with between 29% [49] and 60% [46] having good knowledge of correct temperature setting [48, 50]. Incorrect (high) refrigeration temperature increases the opportunity for pathogenic microorganisms to grow in contaminated food [50].

Socioeconomic status may predict food safety knowledge and consequent behaviour with previous studies reporting that it shapes behaviours of respondents related to household food preparation [45, 46, 48, 51]. These factors should also be considered as an understanding of the knowledge and factors associated with human behaviour is critical for tailored messages on foodborne prevention to be effectively communicated to a larger population.

### **2.3.2 Food preferences**

Food safety hazards arising from climate change and extreme weather events can occur anywhere along the food chain from primary production, processing, distribution and preparation through to human consumption [47]. Human behaviour associated with the warmer seasons such as outdoor eating and barbequing may increase exposure to contaminated food [24]. Barbeques, a method of cooking used more frequently in the warmer seasons, can increase the risk of foodborne disease due to food spoilage, insufficient cooking, cross-contamination between raw and cooked meats, and use of raw marinade on cooked food. Safe food handling practices can become compromised if hand washing facilities are not available, especially if consumers engage in outdoor eating in the warm seasons [52].

Changing food consumption patterns in warmer weather, including a preference for eating out and consuming pre-prepared food and more fresh fruit and vegetables may also contribute to an increase in foodborne illness in the warm weather season [53, 54].

Preferences for eating high-risk foods for *Salmonella* and *Campylobacter* infection in the warmer weather could be potential sources of foodborne pathogens into the home.

Furthermore, it has been postulated that with increasingly warmer weather, consumers may change their shopping behaviour and purchase all their food needs at the one supermarket, or increase their preference for takeaway and home delivery of fast foods [55] which may contribute to an increased risk of foodborne disease.

### **2.3.3 High-risk foods for *Salmonella* infection**

Food is an important route of transmission for *Salmonella* spp. Implicated foods most commonly associated with *Salmonella* outbreaks in Australia have been poultry, eggs, raw meat, milk and other dairy products, fresh produce and fruit juice [56]. A multi-jurisdictional outbreak of *Salmonella* spp. in Australia was associated with purchasing chicken meat from a supermarket chain in 2005 [57], and in a retail chicken survey conducted in SA, the prevalence of *Salmonella* spp. in raw chicken meat was 38% [58]. A New South Wales (NSW) study identified three risk factors associated with sporadic cases of *Salmonella* Birkenhead - consumption of chicken from a fast food outlet, fruit and vegetables not washed thoroughly or peeled prior to consumption, and food cooked at home [59]. As discussed previously, human adaption to climate change in the light of increasing higher temperature may mean a preference for shopping at the one supermarket [60], thereby increasing the risk of foodborne disease with previous salmonellosis outbreaks in Australia linked to high-risk foods purchased from supermarkets [57].

Fresh produce is becoming more frequently associated with *Salmonella* spp. outbreaks [61, 62]. Pathogens can survive for long periods on fresh produce, and if it is not cooked but consumed raw, contamination of produce poses a food safety risk for consumers [63]. In Australia, microbiological testing for pathogens in fresh produce detected *Salmonella* spp. in a strawberry sample collected from the field. Reports of outbreaks in Australia associated with consumption of fresh horticultural produce between 1991 to 2007 implicated orange juice, cucumber, fruit salad, salad, semi-dried tomatoes with fresh garlic, lettuce, sliced red onion, alfalfa, bean shoots (suspected), cantaloupe and paw paw [63]. Likewise, others studies have reported the detection of *Salmonella* following microbiological testing in mixed salad, lettuce, spinach and corn salad [64] and bagged ready-to-eat raw salad [65], all from supermarkets. In summary, a range of commonly

consumed food and juice products are considered to be high-risk foods for *Salmonella* infection and may be consumed more frequently in the summer seasons.

### **2.3.4 High-risk foods for *Campylobacter* infection**

Human infection from *Campylobacter* is thought to occur sporadically rather than in outbreaks. The primary source for *Campylobacter* infection in humans is poultry meat [66]. A case-control study in Australia identified chicken consumption as the main risk factor for *Campylobacter* infection, with a population attributable risk estimate of greater than 50,000 cases each year [67]. A baseline survey in Australia measured the prevalence of *Campylobacter* spp. in chicken meat and found that 64% of the chickens tested on farms were positive and 84% were positive pre and post slaughter [58]. These results are similar to those pertaining to chicken samples at the retail level, including supermarkets in SA [58].

Outbreaks are commonly associated with foodborne transmission as 82% of *Campylobacter* outbreaks in Australia, from 2001 to 2006, were food related [68]. The food source implicated in these outbreaks was chicken, duck, unpasteurised milk and salad [68]. This is similar to other reports of outbreaks due to *Campylobacter* spp. that have implicated a variety of food sources including, poultry meat, unpasteurised milk, beef, pork and shellfish [35].

Appropriate messages to the public about consumption of high-risk foods for foodborne diseases and ways to prevent themselves or their family from becoming ill is critical. In previous studies, the general population surveyed about food safety preferred mass media and print brochures [45], along with electronic media to inform consumers of high-risk food items [46].

In summary, Section 2.3 has highlighted that there is limited information available concerning the social and behavioural practices and knowledge associated with food safety

in relation to climate, and whether these practices change in warmer weather potentially placing consumers at risk of foodborne disease. Previous studies have found that there is a gap in the knowledge and practices of households about food safety, but it is not known if consumers engage in risky behaviour because of warmer weather thus potentially increasing their risk of foodborne disease. Preferences related to dining out, cooking barbeques, and consuming pre-prepared and high-risk foods for *Salmonella* and *Campylobacter* infection may also be associated with practices during warmer temperatures. These gaps in knowledge led to study 1, a survey of the practices, knowledge and preferences of *Salmonella* and *Campylobacter* cases related to food safety.

## **2.4 Effects of warmer ambient temperature on foodborne disease**

### **2.4.1 Impact on the food chain**

Emerging risks to food quality and quantity from climate change are an important issue, since all stages of the food chain can be affected by extreme weather events, including heatwaves. The food system begins with primary production, followed by processing, transportation, retail/trading and kitchen, and finally to human consumption [13].

Pathogens can enter and contaminate the food chain from beginning (farm) to end (fork).

At the primary production stage, contamination can occur through the use of manure or contaminated water to fertilise and irrigate fresh fruit and vegetables [69]. Because

*Salmonella* spp. can survive outside of animal or human hosts, higher ambient temperatures may enhance replication in manure. This may facilitate transmission between animals, particularly in conditions associated with intensive farming and overcrowding [23]. Other pathways through which warmer temperature can impact food safety includes transportation and conditions facilitating pathogen survival on food products to the time they reach the consumer [66, 69]. Extreme weather events may disrupt the distribution of food causing it to spoil if not kept at the required refrigerated temperature [69].

Warmer ambient temperature and heatwaves can have a direct effect on the health of humans via the food chain. With rising temperatures, animal health and plants will be affected, thus altering the quality and quantity of food production, potentially resulting in increasing foodborne disease [70]. High relative humidity and high minimum temperatures give little relief from heat, and not only challenge human health, but livestock health as well [71, 72]. More importantly, higher temperatures can have a negative effect on livestock production with associated mortality during transportation to abattoirs [72]. Animal diseases may increase because of pathogens invading more favourable host environments, for example through the growth of pathogens in animal feed. Bacterial contamination of poultry meat, and livestock carcasses at the time of leaving abattoirs has been found to be higher in summer [72]. For example, heat stress in pigs can increase the number of *Salmonella* spp. and lead to greater contamination on the carcass [72].

Fresh produce including fruit and vegetables, animals and poultry reared in crowded conditions, and seafood are also sensitive to extreme heat [69]. Bacterial pathogens can survive for long periods and multiply in the environment, thus increasing the potential of transmission to food and animal feed. Although *Campylobacter* is sensitive to high temperatures and dry environments, the bacteria survive well in poultry processing production stages [35]. This lends further evidence to poultry meat as a high-risk food for campylobacteriosis.

#### **2.4.2 Impact on human health**

Over the past two decades, studies have presented epidemiological evidence and a description on the impact of the effects of ambient temperature and other climatic variables on gastrointestinal illness. Positive associations of ambient temperature and gastroenteritis have been documented in studies conducted in a limited number of countries. These studies have also reported on the morbidity associated with gastroenteritis. For example, a study in Fiji found that each 1°C increase in temperature was associated with a 3% increase



in risk of diarrhoea [73]. Higher temperature has also been associated with an increase in risk of infectious diarrhoea in Shanghai, China [74].

El Nino-Southern Oscillation (ENSO) has been found to have an effect on ambient temperature and cases of diarrhoea infection. ENSO influences large-scale patterns in climate variability in the Pacific region, Asia and some other parts of the world due to fluctuations in the atmosphere and the equatorial Pacific ocean. This phenomenon usually occurs every three to seven years, but has intensified in the 20<sup>th</sup> century, affecting the global mean temperature due to the exchanges of heat between the ocean and the atmosphere [33]. As a direct consequence of El Nino during 1997 to 1998 the mean ambient temperature in Peru increased by 5%, resulting in a 200% increase in daily hospital admissions [75].

In Australia, hospital admissions for diarrhoeal illness among central Australian Aboriginal children are also likely to increase from 3% to 5% by 2020, and 5% to 18% by 2050, based on projected annual mean temperature increases of 1°C by 2020 and up to 3.5°C by 2050 [15]. These projections are based on incidence of admissions to Alice Springs Hospital between December 1997 and June 2002 for diarrhoeal episodes in children aged less than ten years. During this time diarrhoeal admissions peaked with a lag of one to two months following maximum summer temperatures, indicating a seasonal pattern [15]. In Australia, it was estimated that there would be a 2.48% increase in gastroenteritis cases for every 1°C rise in temperature, and a 13% increased risk of cases for a 5°C rise in temperature [76].

More recently a systematic review and meta-analysis of the effects of ambient temperature and diarrhoeal diseases found a positive association with diarrhoea in general (Incidence Rate Ratio (IRR) 1.07, 95% Confidence Interval (CI) 1.03-1.10) and with bacterial diarrhoea as a cause (IRR 1.07, 95%CI 1.04-1.10), but not diarrhoea attributed to viral pathogens (IRR 0.96, 95%CI 0.82-1.11) [77]. A limitation of this study is that causes of

diarrhoea are rather broad; it may not be infectious in aetiology, and in infectious diarrhoea different pathogens, bacterial or viral, may have different characteristics that are not necessarily related to climate variability as there are other pathways for transmission.

Moreover, data were extracted from only 26 studies, reinforcing the limited information and quantitative analyses available to assess relationships between temperature, specifically in the warm seasons and during heatwaves, with foodborne disease.

Since the mid-2000s studies have focused on specific pathogens with study designs attempting to quantify potential impacts of climate change on disease outcome. Impacts of climate change have been demonstrated through change in incidence, either an increase or decrease, and using more appropriate statistical analyses accounting for time-series data. Uncertainty exists about the causal mechanisms of changes in infectious disease processes affected by climate change [78]. Multiple exposure pathways, host susceptibility and host environment, and pathogen properties including distribution and virulence, add complexity to understanding the effects of temperature on gastrointestinal illness [6, 77].

The next section of the literature review will provide a synthesis of the studies on the relationship between ambient temperature in the warm seasons and heatwaves on *Salmonella* and *Campylobacter* infections. The particular focus of this epidemiological review will be on location of previous studies, temperature measures as the exposure variable, temporal scale, possible confounders, outcome variable, statistical analysis, evidence of an association between temperature and *Salmonella* and *Campylobacter* notifications, consideration of time lag for temperature effects, temperature thresholds and general comments as discussed in the studies. This information will be highlighted in Tables 1 through 4 and referred to throughout the next section.

### **2.4.3 Lag effects and temperature thresholds**

Generally, in studies concerning temperature and mortality or morbidity, it is possible that the exposure may have a delayed or “lagged” effect on the health outcome [79]. Thus, at the stage of model fitting and analyses, lag effects need to be considered.

Lag effects refer to the influence of temperature on mortality or morbidity and such effects are not apparent immediately. Often there is a delayed effect of temperature on outcomes, with human cases occurring sometime after the exposure [79]. Knowledge about the delayed effects of temperature on foodborne infection is important because contamination could occur at any point along the food chain, thus influencing actions in foodborne prevention. For example, the effect of ambient temperature on *Salmonella* incidence in the week prior to onset of illness has implications for food safety, particularly food preparation, handling and storage until the time of consumption [80]. This information could be incorporated as part of an early warning system for community health education campaigns, as opposed to effects felt that pertain to the stage of primary production.

Temperature thresholds are defined as temperatures at which the point in the risk of health outcomes of interest changes. Few studies have attempted to detect threshold temperatures for foodborne disease. The association between temperature and morbidity and mortality is usually U, V or J shaped [81, 82], hence a non-linear relationship of temperature with the outcome is typical. To examine the effects of temperature on health outcomes, the point in the curve at which the change in slope occurs may identify a temperature threshold. Temperature thresholds are used to identify the point above which a change in the relationship with temperature and health outcomes is observed. Such thresholds can provide evidence for interventions, usually through informing the development of early warning systems [81, 83].

## **2.5 Overview of published epidemiological studies on ambient temperature and *Salmonella* infection**

### **2.5.1 *Salmonella* infection**

As shown in Table 1, 12 studies have reported on the effects of ambient temperature and *Salmonella* infection only, and in Table 2, four studies examined a range of enteric infections together with *Salmonella* and *Campylobacter* spp. In total, these 16 studies concerned with *Salmonella* infection and temperature have been reported mainly in Australia and NZ, Europe, England and Wales (hereafter referred to as the United Kingdom (UK)), the United States of America (USA) and Canada. In some regions within Europe it is estimated that one third of *Salmonella* cases are attributed to the influence of ambient temperature [80]. Despite evidence of a positive association between temperature and risk of *Salmonella* infection, there are inconsistencies in study results related to a number of factors involving different temperature metrics to assess exposure, differences in temporal scale and inconsistent use of statistical analysis. Some of these factors will be discussed in this section and in Chapter 3.

Most of these studies in Table 1 and 2 found an association between warmer ambient temperature and enteric infections in different countries and regions including Asia, Europe, the USA, North America and Australasia [52, 84-98]. However, temperature effects and risk of *Salmonella* infection differed within studies that assessed inter-regional and country variations whereby the association was negative. For example, the study by Lal in NZ found no statistically significant association between temperature and risk of *Salmonella* infection for Wellington, but the association was positive for Auckland and Christchurch [93]. Similarly, an international study covering many countries in Europe found a null relationship for increased salmonellosis and temperature for the Slovak Republic (Slovakia) and Denmark but reported positive associations for the other countries [91]. In Canada, a positive association was identified in Alberta, but a negative association between increased risk of *Salmonella* infection and temperature was reported in

Newfoundland-Labrador [87]. Variation in relationships between temperature and salmonellosis exists, probably because of local climatic factors affecting disease transmission and environmental routes [15].

As highlighted in Table 1 and 2, and based on availability of data, the studies reported that a 1°C increase in maximum or mean temperature may lead to between 1% and 20% extra salmonellosis cases. In one study, a 5°C increase in temperature led to some 45% extra cases [95]. Not all studies [52, 92, 96] interpreted their results as percent change in *Salmonella* counts per °C increase in maximum temperature. Nevertheless, these studies reported a statistically significant and positive association between temperature and risk of infection.

Of the four studies conducted in Australia, two examined temperature and salmonellosis relationships in SA [86] then Adelaide [97]. The study in Adelaide by Zhang found that the expected weekly increase in the number of cases for 1°C rise in maximum temperature ranged from 10% to 20%, depending on the statistical model that was fit [97]. A national study of capital cities in Australia [86] identified an increase in risk of cases by 5% each month for 1°C rise in maximum temperature in Adelaide. Risk of increase in salmonellosis cases related to temperature was also reported in Queensland, Australia. This risk varied between regions with subtropical [95] [98] and tropical climates [98]. This finding highlights the inter-regional variation associated with temperature and the need to consider local climatic factors when assessing the effects of temperature on health outcomes.

The effect estimates for temperature and risk of infection also varied across temporal scales. A number of studies used weekly counts and temperature data [87, 90, 92, 93, 96, 97], and others used month [24, 31, 84-86, 88, 89]. Two studies assessing the relationship between temperature and risk of salmonellosis within multiple geographic regions used weekly, fortnightly and monthly data because of data availability and the relatively small

number of *Salmonella* notifications [91, 98]. Only one study, conducted in Australia, used daily salmonellosis counts and daily temperature data [95]. The estimates in all these other studies are based on *Salmonella* spp. counts aggregated by week or month. Daily disease notifications may be more sensitive in detecting variability in temperature than weekly or monthly aggregated data as daily notifications should align better with climate data [99]. Analysis of data may also provide a more sensitive analysis of the timing of temperature effects on risk of disease.

Generally an increased risk of salmonellosis was greater in regions with temperate, tropical and subtropical climates with higher mean or maximum temperatures [85, 86, 91, 93-95, 97, 98]. It is important to examine the effect of climate variability on daily *Salmonella* infections, and to consider the lagged effect. Furthermore, it will be advantageous for local health authorities to detect temperature thresholds for public health interventions.

### **2.5.2 *Salmonella* serotypes**

Few studies have examined the impact of temperature on *Salmonella* serotypes and so we have little evidence about whether serotypes have different modes of transmission related to temperature [92]. Differentiating *Salmonella* strains related to environmental exposure and those specifically affected by warmer temperature and heatwaves can point to possible sources of infection, providing useful information for public health practices in disease control and prevention.

Only three studies [91, 92, 96] considered the effect of temperature on serotypes but there was no further examination of an association with temperature and different *Salmonella* phage types. *Salmonella* phage typing is used to characterise strains within particular serotypes, and provides useful information for epidemiological purposes such as identifying pathways for transmission, and sources of infection in outbreak investigations [100]. *Salmonella* Enteritidis and *S.*Typhimurium notifications across two studies were

positively associated with temperature [91, 92]. However, the effects of temperature on salmonellosis counts varied. In the study by Kovats [91] only the Netherlands and the UK were able to identify serotypes, with *S.Enteritidis* more sensitive to the effects of temperature than *S.Typhimurium*. The study in Germany reported no effect of temperature on *S.Typhimurium* but a positive association with temperature and *S.Enteritidis* [96]. This points to variations in geographical and climatic regions influencing the prevalence of *Salmonella* spp. serotypes and transmission pathways [29]. The study locations were in Europe and the UK limiting applicability to Australia. *S.Typhimurium*, which was examined against temperature and increased salmonellosis counts, is a commonly reported serotype in Australia as well as in other countries. The other serotype, *S.Enteritidis* included in the studies is not commonly reported in Australia but it is in Europe [101].

### **2.5.3 Lag effects**

#### *Salmonella*

Various time lags have been detected across the 16 studies with delayed effects of temperature on *Salmonella* notifications reported to be between one to eight weeks [52, 86-94, 96-98]. Lag effects were not reported in two studies [84, 95], while there was no delayed effect of temperature identified in a NZ study [85]. Of the studies specific to Australia, an association between temperature and incidence in different climatic regions was reported, however the lag effects varied between the studies, with no lag effect found in Townsville compared to Brisbane (capital city of Queensland) of two weeks [98]. Further to this, a lag of one month was found in five Australian states, including SA. D'Souza identified a positive association between mean temperature of the previous month and the number of salmonellosis cases in the current month in five Australian states, including SA [86]. Zhang et al [97] reported that in Adelaide, temperature in the previous two weeks was associated with *Salmonella* cases.

### *Salmonella* serotypes

In two separate studies in the UK temperature effects were strong at one and two week lags, but persisted up to five weeks with *S.Typhimurium* and *S.Enteritidis* cases [91], and up to five weeks for *S.Typhimurium* [92]. The study by Kovats [91] also reported that *S.Typhimurium* had a stronger association with temperature in the previous two to five weeks compared to *S.Enteritidis*. Similar to the findings reported in the UK, a study in Germany reported a lag of five weeks associated with *S.Enteritidis* cases [96]. The transmission pathways for *Salmonella* serotypes and phage types may be a reason for the differences in lag effects found across studies [92].

#### **2.5.4 Temperature thresholds**

Very few studies examined temperature thresholds. Of those that did, the relationships between *Salmonella* cases and temperature was generally linear above thresholds of  $\sim 10^{\circ}\text{C}$  and between  $0\text{-}6^{\circ}\text{C}$ , [87, 91] and  $20\text{-}27^{\circ}\text{C}$  [93]. No temperature thresholds were found in a study in Adelaide, Brisbane and Townsville [97, 98] or in Russia and Kazakhstan [88, 89]. Temperature thresholds were estimated in countries with milder climates than Australia, and analysis was not restricted to the warmer months. Further, there is evidence to support that the risk of salmonellosis is likely to increase with much higher temperature as highlighted in a study by Lal [93] who found that increases in notifications followed cool and hot temperatures, with a greater increase in salmonellosis associated with higher temperatures.



**Table 1 Epidemiological review of studies that examined the relationship between ambient temperature and *Salmonella* infection.**

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Stephen 2016	South-east Queensland (Australia)	2004-2013	14,800	Mean temperature	Daily	Time-series, Poisson regression, Autoregressive regression	5°C ↑ in temperature associated with 45.4% ↑ cases	Lag NR Threshold NR	Control for season, long-term trend, day of week, holidays, auto-correlation & outbreaks	Did not use date of symptom onset Average of regional weather recordings Travel not identified No data on serotypes
Lal 2016	Auckland Wellington Christchurch (New Zealand)	1997-2007	4,857	Maximum temperature	Weekly	Time-series, DLNM	RR of salmonellosis associated with ↑ in temperature (Auckland & Christchurch)	Lag 2-6 weeks Threshold of 20-27°C	Control for season, long-term trend	Travel not identified No data on serotypes
Grijbovski 2014	Kazakhstan (4 regions)	2000-2010	10,437	Mean temperature	Monthly	Time-series, Negative binomial regression	1°C ↑ in temperature associated with 5.5% ↑ cases (Astana) Negative association in other 3 regions	Lag 2 months in Astana (capital of Kazakhstan) Threshold not detected	Control for season, year-variations, auto-correlation	Outbreaks/travel not identified No data on serotypes
Akil 2014	Mississippi Tennessee Alabama (United States of America)	2002-2011	NR	Average temperature (maximum)	Monthly	Time-series	1°F ↑ in temperature associated with 3% ↑ cases (Mississippi only)	Lag NR Threshold NR	Control for season	Only analysed outbreak cases Combined states in models No data on serotypes
Grijbovski 2013	Arkhangelsk (northern Russia)	1991-2008	4,585	Mean temperature	Monthly	Time-series, Negative binomial regression	1°C ↑ in temperature associated with 1.8% to 2.3% ↑ cases	Lag 1 month Threshold not detected	Control for season, year-variations, long-term trend, auto-correlation Outbreak cases excluded	Travel not identified No data on serotypes

Table 1 Epidemiological review of studies that examined the relationship between ambient temperature and *Salmonella* infection. (cont'd)

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Kendrovski 2011	Skopje (Republic of Macedonia)	1998-2008	3,890	Maximum temperature	Weekly	Time-series, Poisson regression	1°C ↑ in temperature associated with 5.2% ↑ cases	Lag 1 month Threshold NR	Control for season	Outbreaks/travel not identified No data on serotypes
Ravel 2010	Canada	2005-2008	216	Mean maximum temperature	Monthly	Time-series, Poisson regression, Case-case approach	Monthly cases associated with mean temperature ( $p < 0.001$ )	Lag 1 month Threshold NR	Controlled for season, year-year variations	Number of cases was limited
Zhang 2010	Brisbane Townsville (Queensland, Australia)	1990-2005	5,294 in Brisbane 1,170 in Townsville	Maximum temperature	Weekly & monthly	Time-series, Poisson regression	1°C ↑ temperature associated with 8.8% ↑ cases (Brisbane) 1°C ↑ temperature associated with 11.9% ↑ cases (Townsville)	Lag 2 weeks (Brisbane) Lag 0 month (Townsville) Threshold not detected	Control for season, year-year variations, long-term trend, auto-correlation Outbreak cases excluded	No data on serotypes
Britton 2010	New Zealand	1965-2006	NR	Mean temperature	Monthly	Time-series, Negative binomial regression	1°C ↑ temperature associated with 15% ↑ cases	Lag 0 month Threshold NR	Control for season, long-term trend, auto-correlation, outbreak month	Nationally averaged temperature data Travel not identified No data on serotypes
Zhang 2008	Adelaide (South Australia, Australia)	1990-2003	4,740	Maximum temperature	Weekly	Time-series, Poisson regression, Autoregressive adjusted Poisson, Multiple linear, SARIMA	1°C ↑ in temp associated with 5% to 20% ↑ cases	Lag 2 weeks Threshold not detected	Control for season, year variations, long-term trend, auto-correlation Outbreak cases excluded	No data on serotypes

Table 1 Epidemiological review of studies that examined the relationship between ambient temperature and *Salmonella* infection. (cont'd)

Reference	Location	Study period	Sample size (number of cases)	Temperature measurements	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
D'Souza 2004	Perth Adelaide Melbourne Sydney Brisbane (Australia)	1991- 2001	NR	Mean temperature	Monthly	Time-series, Negative binomial regression	1°C ↑ temperature associated with ↑ of cases of 10% for Brisbane, 6% Sydney, 5% Melbourne & Adelaide, 4% Perth	Lag 1 month Threshold NR	Control for season, year-year variations, long-term trend, auto-correlation, outbreak month	No data on serotypes
Kovats 2004	Czech Republic Denmark England/Wales Estonia Netherlands Scotland Slovakia Poland Switzerland Spain	Range varied from 1984- 2002	Average annual total varied from 840-40,970	Mean temperature	Weekly, fortnightly or monthly	Time-series, Poisson regression	1°C ↑ temperature associated with ↑ of overall cases of 2%-13% for all countries except Denmark & Slovakia 1°C ↑ temperature associated with ↑ of cases of 6%-13% for England/Wales & Netherlands by serotype (S.Enteritidis, non-S.Enteritidis & S.Typhimurium)	Lag 1-9 weeks for overall cases Lag 1-5 weeks for S.Enteritidis/ S.Typhimurium (England/Wales) Estimated common threshold of 6°C for all countries Threshold not detected Denmark, Slovakia & Estonia	Control holiday, inter-annual variation, auto-correlation	Single national temperature data Not all outbreaks/ travel identified

NR – Not recorded; DLNM - Distributed Lag Non-Linear Model; RR – Relative Risk; SARIMA – Seasonal Autoregressive Integrated Moving Average model

**Table 2 Epidemiological review of studies that examined the relationship between ambient temperature and *Salmonella* and *Campylobacter* infection.**

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Disease type	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Yun 2016	Munich Berlin (Germany)	2001- 2004	NR	Maximum temperature	<i>S.Enteritidis</i> <i>S.Typhimurium</i> <i>Campylobacter</i>	Weekly	Time-series, Negative binomial regression	↑ temperature positively associated with an ↑ in <i>S.Enteritidis</i> & <i>Campylobacter</i> incidences plateaued at temperatures above 18°C	Lag 5 weeks ( <i>S.Enteritidis</i> ) Lag 3 weeks ( <i>S.Typhimurium</i> ) Lag 4-7 weeks ( <i>Campylobacter</i> )	Control for trend	Outbreaks/ travel not identified
Lal 2013	New Zealand	1997- 2008	14,804 ( <i>Salmonella</i> ) 79,193 ( <i>Campylobacter</i> )	Mean temperature	<i>Salmonella</i> <i>Campylobacter</i>	Monthly	Time-series, SARIMA	Temperature associated with <i>Salmonella</i> cases ( $p<0.001$ ) No relationship with temperature & <i>Campylobacter</i> cases	Lag 1-2 months ( <i>Salmonella</i> ) Lag 0 months ( <i>Campylobacter</i> ) Threshold NR	Control for season, long-term trends, auto-correlation	Outbreaks/ travel not identified No data on serotypes
Lake 2009	England Wales	1974- 2006	NR	Mean temperature	<i>Salmonella</i> <i>S.Enteritidis</i> <i>S.Typhimurium</i> <i>Campylobacter</i>	Weekly	Time-series	↑ temperature positively associated with an ↑ in <i>S.Enteritidis</i> , <i>S.Typhimurium</i> , <i>Salmonella</i> , <i>Campylobacter</i>	Lag 2-5 weeks ( <i>Salmonella</i> & <i>S.Typhimurium</i> ) Lag 0 week ( <i>Campylobacter</i> ) Threshold NR	Control for season, holidays, long-term trends, auto-correlation Travel cases excluded	Use of date of specimen Use of weighted mean temperature Outbreaks not identified

Chapter 2 Literature Review

Table 2 Epidemiological review of studies that examined the relationship between ambient temperature and *Salmonella* and *Campylobacter* infection. (cont'd)

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Disease type	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Fleury 2006	Alberta Newfoundland-Labrador (Canada)	1992-2000	6,282 ( <i>Salmonella</i> , Alberta) 1,743 ( <i>Campylobacter</i> , Alberta) 986 ( <i>Salmonella</i> , Newfoundland) 1,188 ( <i>Campylobacter</i> , Newfoundland)	Mean temperature	<i>Salmonella</i> <i>Campylobacter</i>	Weekly	Time-series, GLM, GAM	1°C ↑ in temp associated with 1.2% ↑ <i>Salmonella</i> (Alberta) Negative association temperature & salmonellosis (Newfoundland) 1°C ↑ in temp associated with 2.2% ↑ <i>Campylobacter</i> (Alberta) 1°C ↑ in temp associated with 4.5% ↑ <i>Campylobacter</i> cases in (Newfoundland)	Lag 0-6 weeks Threshold - 10°C Alberta Threshold >0°C Newfoundland	Control for season, long-term trends, auto-correlation, holidays, health region	Outbreaks/travel not identified

NR – Not recorded; SARIMA – Seasonal Autoregressive Integrated Moving Average model; GLM - Generalized Linear Model; GAM - Generalized Additive Model

## **2.6 Overview of published epidemiological studies on ambient temperature and *Campylobacter* infection**

As summarised in Table 3, seven studies have reported on the effects of ambient temperature and *Campylobacter* infection only, and in Table 2, four studies which examined a range of enteric infections together with *Salmonella* and *Campylobacter* spp. Of the combined studies, most have been reported from Europe and the UK [92, 96, 102-104], and the USA and Canada [87, 105, 106]. Three studies have examined data from Australia and NZ, one was a multi-city study including Europe, Australia and NZ [107], one was in NZ only [94] and the other compared Adelaide and Brisbane [99].

*Campylobacter* infections have a less clear relationship with temperature and climate variability. Some studies report a positive association [87, 92, 96, 102-106] between increasing temperature and incidence of cases and others an inverse or no relationship [94, 107]. Not all studies reported effect estimates as a percentage change in notifications per unit increase in temperature, but of those that did, a 1°C increase in maximum or mean temperature may lead to an estimated 0.8% to 5% extra *Campylobacter* cases [104-106].

Australia was the location for two studies. First, the study by Bi [99] found that *Campylobacter* cases notified in Brisbane were positively associated with mean temperature, yet in Adelaide he found an inverse relationship. It is postulated that this difference could be associated with weather conditions specific to that area which could have an impact on animal reservoirs or processes along the food chain [99]. Second, Kovats [107] did not find a strong effect with temperature and increased risk of *Campylobacter* infection in the multi-city study. For all of the studies in Table 2 and 3, weekly data for temperature and *Campylobacter* counts was used, with the exception of one that used monthly counts [94].

### **2.6.1 Lag effects**

Generally, lags that were identified ranged from one to six weeks. Studies that identified long lags of eight weeks or more were those that had a null effect of temperature on *Campylobacter* cases [99, 107], with the exception of Lal et al who reported no lag effects in a NZ study [94].

### **2.6.2 Temperature thresholds**

Studies reporting a positive association of temperature and increased incidence of campylobacteriosis experience much cooler climates than Australia with some identifying temperature thresholds of between  $>0^{\circ}\text{C}$  to  $14^{\circ}\text{C}$  [87, 94, 103-105]. The study in Germany found that incidence of *Campylobacter* cases plateaued at temperatures above  $18^{\circ}\text{C}$ , providing further evidence of an association with cooler temperature and campylobacteriosis [96].

**Table 3 Epidemiological review of studies that examined the relationship between ambient temperature and *Campylobacter* infection.**

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Allard 2010	Montreal (Canada)	1990-2006	Not recorded	Mean temperature	Weekly	Time-series, Negative binomial regression	1°C ↑ temperature above 10°C associated with 0.8% ↑ cases	Lag 1-6 weeks Threshold 10°C	Control for season, holidays	Outbreaks/travel not identified Date of notification used Temperature effects small
White 2009	Philadelphia (United States of America)	1994-2007	1,477	Mean temperature	Weekly	Time-series, Poisson regression, Case-crossover	1°C ↑ temperature associated with 4.1% ↑ cases	Lag 4 weeks Threshold NR	Control for season, long-term trend	Weather data from single site averaged over several locations Outbreaks/travel not identified
Bi 2008	Adelaide Brisbane (Australia)	1990-2005	20,211 (Adelaide) 14,697 (Brisbane)	Maximum temperature	Weekly	Time-series, Poisson regression	Negative association with temperature (Adelaide) Weekly cases associated with temperature ( $p$ 0.001) (Brisbane)	Lag 9 weeks (Adelaide) Lag 6 weeks (Brisbane) Threshold NR	Control for season, long-term trends, auto-correlation	Outbreaks/travel not identified
Tam 2006	England	1989-1999	623,817	Mean temperature	Weekly	Time-series	1°C ↑ temperature associated with 5% ↑ cases	Lag 6 weeks Threshold 14°C	Control for season, long-term trends, holidays	Specimen date Indirect method to exclude travel cases Aggregated Central England temperature High variability of data



Chapter 2 Literature Review

Table 3 Epidemiological review of studies that examined the relationship between ambient temperature and *Campylobacter* infection. (cont'd)

Reference	Location	Study period	Sample size (number of cases)	Temperature measurement	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Louis 2005	England Wales	1990-1999	401,270	Maximum temperature	Weekly	Time-series	Daily average temperature associated with cases ( $p < 0.001$ )	Lag 0 weeks Threshold NR	Control for season, auto-correlation Outbreaks/ravel excluded	Use of specimen date
Kovats 2005	Czechoslovakia Denmark England/Wales Netherlands Scotland Greece Estonia Ireland Malta Switzerland Spain New Zealand Australia	Range varied 1989-2002	Average annual total varied from 22 to 39,334	Mean temperature	Weekly	Time-series, Poisson regression, Conditional logistic regression	No strong effect of temperature on cases	Lag 10-14 weeks Threshold NR	Control for season, timing of peak of cases Travel cases excluded for some countries	Representative temperature series for Europe and New Zealand Use of aggregated Central England temperature Lack of data from some countries Lack of long time series for some countries (>10 years)
Patrick 2004	Denmark	1998-2001	16,305	Mean temperature	Weekly	Linear regression	Largest increase in incidence at temperatures above 20°C	Lag 4 weeks Threshold average temperature >8°C & maximum temperature above 13°C	Travel cases excluded	Regional climate variation not examined

NR – Not recorded

## 2.7 Effect of heatwaves on foodborne disease

There is an extensive body of literature on the relationship of mortality and morbidity associated with heatwaves. For example, studies have reported on the mortality burden associated with significant heatwave periods in Chicago [108], France [109], California [110], China [111] and England [112]. At the same time, other studies have reported on the morbidity associated with heatwaves encompassing those related to renal disease [3], respiratory, cardiovascular disease and heat stroke [113], and mental illness [114].

Surprisingly, there is a paucity of information on the effects of heatwaves on gastrointestinal infection and none specifically pertaining to *Salmonella* and *Campylobacter* infection. Extreme weather events, such as heatwaves that are likely to become more frequent if the average ambient temperature becomes warmer, will have an impact on food production, distribution and may alter our behaviour as food consumers [23]. A better understanding of the likely mechanisms on the effects of heatwaves on infectious gastroenteritis is needed so that public health messages can be targeted most effectively to those at greatest risk.

As no information is available on the effects of heatwaves on *Salmonella* and *Campylobacter* infection, in its place reference is made to two studies on heatwaves and gastrointestinal infection. One study located in Brisbane [115], and the other in Europe (Zurich, Switzerland) [116], examined the effects and characteristics of heatwaves on gastrointestinal infection, but not specifically on *Salmonella* or *Campylobacter* infection. Both found a significant association between heatwaves and emergency department visits for childhood diarrhoea [115] and hospital admission for infectious gastroenteritis [116]. As illustrated in Table 4, heatwave definitions varied taking into account length of heatwave days, from two to four [115] and up to six consecutive days [116] and temperatures above a certain threshold. Intensity (above 99<sup>th</sup> percentile) and duration (three days) were associated with hospital emergency department visits for childhood

diarrhoea [115], and hospital admissions for infectious gastroenteritis increased by 4.7% with every additional day in a heatwave [116]. No lag effects were identified in the Brisbane study as the effect occurred on the same day of exposure [115], and in Zurich the greatest risk in an increase of gastroenteritis-related hospital admissions was at seven days after exposure to heatwaves [116].

## **2.8 Summary of methods from previous studies**

As there are few reported studies on the impact of warm season temperature and heatwaves on foodborne disease, a review of the analytic approaches used in existing studies that examined the relationship between ambient temperature, and more broadly infectious gastroenteritis, including the studies on heatwaves and foodborne illness was conducted. In addition, studies of heatwaves on mortality and morbidity were reviewed to assess the type of approaches used to investigate and measure the relationship between heatwaves and other health outcomes. Combined, these reviews assisted in developing the methods and analysis appropriate for this study on warmer temperatures and heatwaves and foodborne disease, and will be further discussed in Chapter 3.

Methods to quantify the effects of ambient temperature and heatwaves on health have ranged from observational studies, such as case-control and case-series, to statistical modelling describing the complex associations between climate variability and health outcomes. Spatial analytic techniques have been increasingly used to investigate heat-health relationships of vulnerable groups at specific locations and in areas of differing socioeconomic levels [117]. The most common study designs used in environmental epidemiology to quantify the human health effects associated with ambient temperature and heatwaves are ecological studies. These will be described in more detail in the next chapter, Chapter 3, along with the application of newer methods and analysis in this thesis. These methods include Generalized Estimating Equations, estimation of temperature

thresholds and use of Distributed Lag Non-Linear models so as to model the effects of temperature on *Salmonella* and *Campylobacter* counts.

**Table 4 Epidemiological review of studies that examined the relationship between heatwaves and gastrointestinal infection.**

Reference	Location	Study period	Sample size (number of hospital patients/visits)	Heatwave definition	Temporal scale	Statistical analysis	Results	Lag effects & temperature thresholds	Controlling for confounding	Comments
Xu 2014	Brisbane (Queensland, Australia)	2001–2010	58,166 (EDV)	Mean temperature Intensity (95 <sup>th</sup> & 99 <sup>th</sup> percentile) Duration (2-4 days above hot threshold)	Daily	Time-series, Poisson regression, GLM, DLNM	HW $\geq 2$ days at 99 <sup>th</sup> percentile $\uparrow$ EDV 3 days for diarrhoea (95% CI 1,5) HW $> 3$ days at 99 <sup>th</sup> percentile $\uparrow$ EDV 7 days for diarrhoea (95% CI 2,13)	Lag 0-1 days Threshold 29.6°C (99 <sup>th</sup> percentile)	Control for season, long-term trends, day of week, holidays	Did not have pathogen data No significant relationship between temperature & bacterial diarrhoea Did not control for other confounders
Manser 2013	Zurich (Switzerland)	2001–2005	786 (patients with IG)	Maximum temperature (MT) 6 days with MT 5°C above daily average MT	Daily	Time series, Poisson regression	HW $\uparrow$ risk of IG admissions by 4.7% for every additional day within a HW Lag 7 days $\uparrow$ risk of IG admissions by 7.2%	Lag 7 days	Control for season, long-term trends, day of week, holidays	Did not have pathogen data Did not control for confounders – smoking status, humidity, misclassification data

EDV – Emergency department visits; IG – Infectious gastroenteritis; GLM - Generalized Linear Model; DLNM - Distributed Lag Non-Linear Model; HW – Heatwave

## 2.9 Gaps in evidence and research justification

In summary, this chapter reviewed the current literature related to human behaviour, food preferences and food safety practices that may be influenced by warmer weather, and the literature concerning the effects of temperature and heatwaves on *Salmonella* and *Campylobacter* notifications. Section 2.3 has highlighted that there are no population-based studies pertaining to food related behaviours and practices specific to seasons, in particular warm weather. We were also interested in understanding if socioeconomic status influenced food safety practices, as evidence suggests that risky behaviours increase with socioeconomic positioning [51]. All these factors should be accounted for when designing intervention strategies to inform the population about food safety, and led to the development, analysis and interpretation of study 1 in this thesis.

Generally, the evidence confirms that an association exists between ambient temperature and *Salmonella* infection, although the relationship is less clear for *Campylobacter* spp. Many of the published studies did not focus on examining associations during the warm seasons, nor did they identify temperature thresholds. This lack of evidence highlights a gap in the knowledge and ascertainment in determining the likelihood of an increased risk of infection with higher temperature. This is relevant given that if foodborne disease varies in prevalence with ambient temperature, then even hotter temperatures may have more impact, thus contributing to the significance of this study.

Given the increasing frequency and intensity of heatwaves in Australia, and the growing public health significance associated with foodborne disease, it is surprising that there are no published studies on the relationship between heatwaves and the incidence of foodborne illness including *Salmonella* and *Campylobacter* spp. Moreover, evidence is required to show that there may be greater sensitivity to increased ambient temperature among different *Salmonella* serotypes and phage types. *Salmonella* serotypes may be more endemic in the environment and thus not likely to be associated with food but with other

environmental exposures, such as climate variations. There is a dearth of literature concerning this association, and so it remains unclear if *Salmonella* serotypes have different sensitivity to climate variables associated with increased temperature.

On the whole, the majority of studies described in this literature review used time-series analysis and appropriate statistical models to predict the expected number of daily, weekly or monthly outcomes as a function of exposure levels [118]. The main unit of analysis for the outcome variable, being *Salmonella* or *Campylobacter* notifications reported from disease surveillance systems, used weekly or monthly counts making it less sensitive in detecting variability in temperature [82, 99]. Effect estimates were not always presented as IRR or Relative Risks (RR) with 95% CI and reported with results interpreted as percent change in the number of disease counts per degree increase in temperature. This makes it difficult to assess the magnitude of the effects of temperature and heatwaves as the association with morbidity usually follows a U, V or J shaped curve [82].

Most studies in this review accounted for some confounders with inclusions of variables indicating holidays and day of the week in statistical models. However, few studies in this review were able to identify outbreak cases and thus exclude them from the analysis. Cases linked to outbreaks should be excluded from the analysis as the relationship of temperature may be different for those with a common exposure compared to sporadic cases with no identified source of infection [86, 91, 98].

Exposure measurements across the studies, including definitions of a heatwave, varied with the mean temperature a common indicator. Several temperature metrics have been constructed and calculated to measure or predict mortality and morbidity associated with temperature exposure and for monitoring heatwaves. These include maximum, minimum, mean and apparent temperature [119]. The methodological issues around using temperature metrics and heatwave definitions will be discussed in the next chapter.

Most studies explored lag structures between exposure to temperature and heatwaves and the number of *Salmonella* and *Campylobacter* cases; however the timing of lags remains undetermined. Very few studies applied temperature thresholds to the statistical analysis, with the few that did unable to find temperature cut points.

More importantly the studies in this review have highlighted that interpretation of results from international studies, and from regions with different climates to that of Australia and more specifically Adelaide, needs to be made with caution because of the varying environmental, socioeconomic and climatic conditions that prevail between continents, countries and regions. All these factors may have an impact on disease transmission and case incidence [99].

### **2.9.1 Research aims**

The aim of this study is to quantify the relationship between warmer ambient temperature and heatwaves and the incidence of *Salmonella*, *Salmonella* serotypes and phage types, and *Campylobacter* infections in Adelaide. In addition, this study will explore whether human behaviour and practices related to food safety changes in the warm season months. The results from this research will contribute further knowledge about the burden of foodborne disease associated with warmer ambient temperature and heatwaves and provide recommendations for prevention. The specific aims of the four studies to be addressed in this thesis are as follows:

1. To assess food safety practices, food shopping preferences and eating behaviours of people diagnosed with *Salmonella* or *Campylobacter* infection in the warm seasons, and to identify if socioeconomic status is associated with their behaviour and practices;
2. To examine the relationship between warmer ambient temperature and the incidence of *Salmonella* and serotypes;



3. To examine the relationship between heatwaves and the incidence of *Salmonella* and serotypes;
4. To examine the relationship between warmer ambient temperature, heatwaves and the incidence of *Campylobacter* infection.

The final aim was to provide scientific evidence for public health policy making and practical guideline development for foodborne disease control and prevention in the context of climate change.

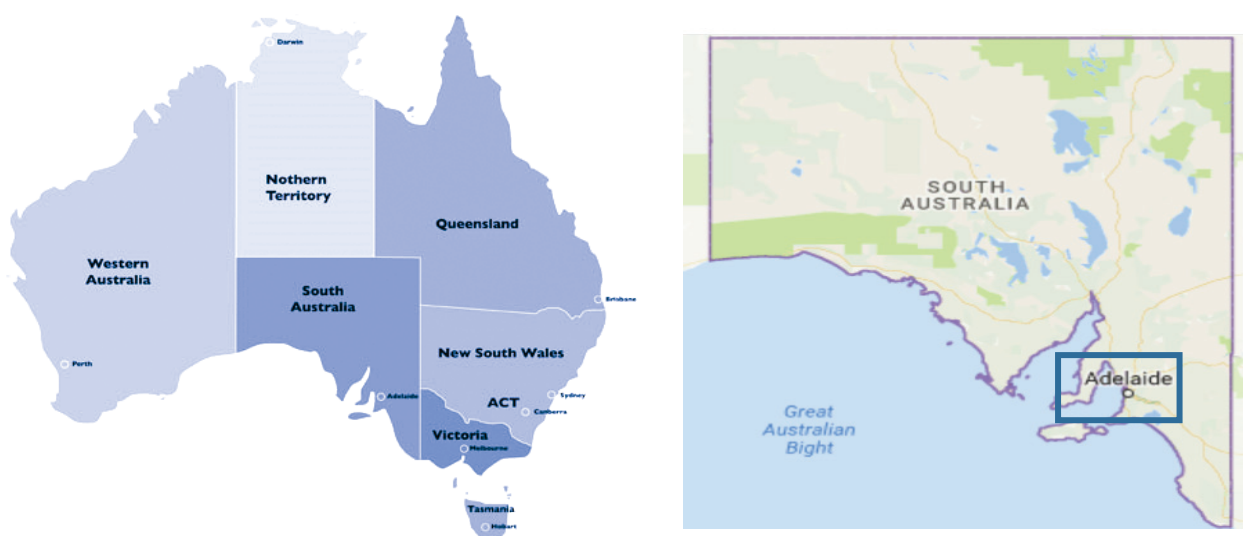
## Chapter 3 Study design and methods

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The aims of this thesis, a review of the literature, and research justification were presented in Chapter 2. The present chapter describes the study region, framework of the study and the analytical approach taken to answer the aims specific to each of the four studies in this thesis.

### 3.1 Study setting

Adelaide is the capital city of South Australia which is a state in the southern part of Australia (Figure 1). In 2015 the population in SA was 1.7 million people, and in Adelaide the population was 1.32 million [120]. Since the 1970s there has been a decrease in rainfall over most parts of the state, with Adelaide considered to be the driest capital city in Australia. Adelaide's climate is temperate with mild winters and hot, dry summers favouring ideal temperatures for foodborne disease pathogen growth. In Adelaide, the annual average number of days above 35°C is 17 days; by 2030 this is estimated to increase to 21-26 days [14].



**Figure 1 The location of Adelaide, South Australia.**

Source: Adapted from Google maps

## 3.2 Research questions

In order to achieve the aims of this thesis and address the highlighted research gaps presented in Chapter 2, this thesis will use quantitative methods to explore the following research questions linked to each of the four studies:

**Study 1 research questions:** Are food safety practices, food shopping preferences and eating behaviours of people diagnosed with *Salmonella* and *Campylobacter* infections influenced by warm weather? Is behaviour and knowledge of safe food handling practices, and perceptions and knowledge about food safety information of *Salmonella* and *Campylobacter* cases influenced by socioeconomic status?

**Study 2 research questions:** Is there a relationship between warm season temperature and incidence of *Salmonella*, and *Salmonella* serotype and phage type notifications in Adelaide; and is there an effect of temperature thresholds on daily *Salmonella* and serotypes and phage types ?

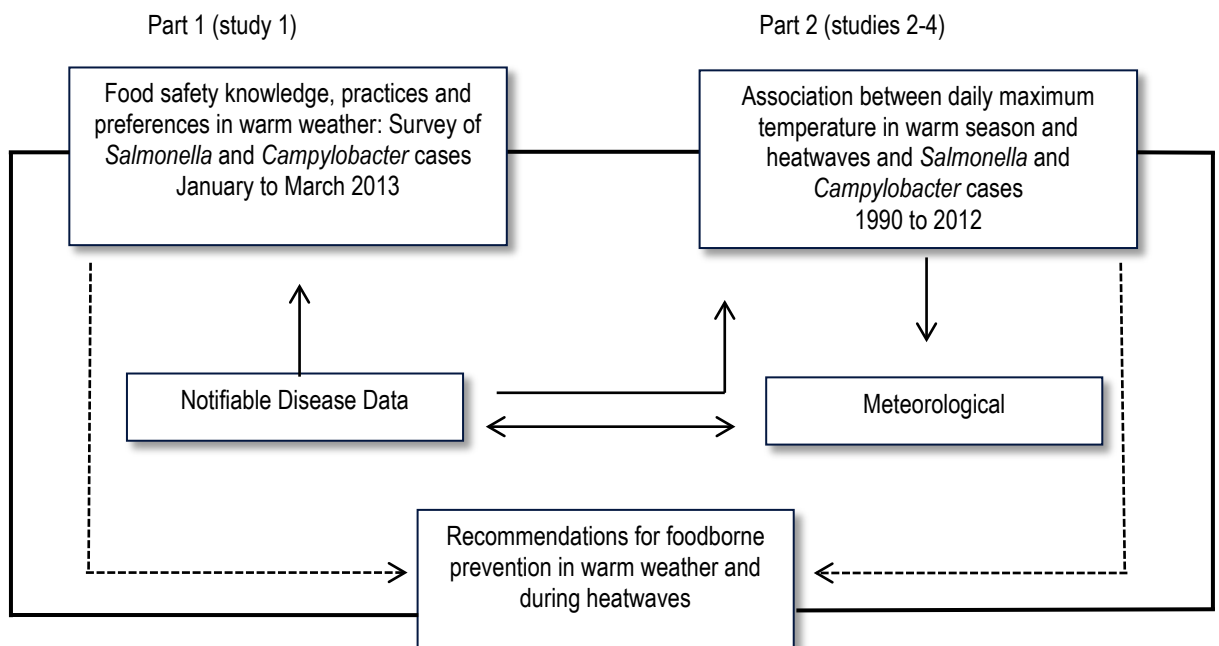
**Study 3 research questions:** Is there a relationship between heatwaves and incidence of *Salmonella*, and *Salmonella* serotype and phage type notifications in Adelaide; and is there an effect of temperature thresholds on daily *Salmonella* and serotypes and phage types?

**Study 4 research questions:** Is there a relationship between warm season temperature and heatwaves and incidence of *Campylobacter* notifications in Adelaide; and is there an effect of temperature thresholds on daily *Campylobacter* notifications?

## 3.3 Framework of the overall study

To address the overall aims and proposed research questions, this thesis is divided into two broad parts. As illustrated in Figure 2, the first part pertaining to study 1 used responses from a cross-sectional survey to elicit information about food safety practices, eating behaviours and preferences in warm weather, as well as knowledge related to safe food handling practices, and perceptions and knowledge about food safety information of

*Salmonella* and *Campylobacter* cases. Cases were residents of SA and notified to the CDCB between January and March 2013. The second part, comprising studies 2 to 4, used analyses of 23 years of time-series data to quantify the association between warm season temperature (and heatwaves) and the incidence of *Salmonella* and *Campylobacter* notifications, and to investigate if specific *Salmonella* serotypes and phage types predominate in hotter temperatures. Notified cases were resident of metropolitan Adelaide with reported illness from 1990 to 2012. Information for all studies was obtained from two administrative datasets. Infectious disease surveillance data from the state health department was utilised for all of the studies presented in Chapters 4, 5, 6 and 7; and the second dataset comprised climate data from the Bureau of Meteorology (BOM) for the studies described in Chapters 5, 6 and 7. Study 1 will help to answer the first research questions, with the remaining research questions informing the results for studies 2 to 4.



**Figure 2 Study framework.**

### **3.4 Data sources and collection**

A dataset that merged the number of notifications for *Salmonella* (serotypes and phage types), and *Campylobacter* and meteorological variables for each day across the time period 1990 to 2012 was created.

#### **3.4.1 Disease notification data**

Under the *South Australia Public Health Act 2011*, medical practitioners and laboratories are mandated to report notifiable diseases to the state health department - SA Department for Health and Ageing (hereafter referred to as SA Health) who are responsible for conducting state wide surveillance. National surveillance case definitions are applied to each notification, and data are entered into the South Australia Notifiable Infectious Disease Surveillance Database (NIDS) [121]. Laboratory confirmed *Salmonella* and *Campylobacter* cases were included in the analyses of all studies. Information was collected on date of onset of illness, age, gender, postcode of residence, outbreak associated and travel. Data were also extracted for *Salmonella* serotypes and phage types.

#### **3.4.2 Meteorological data**

Daily maximum temperature recordings were sourced from BOM, Kent Town weather station, located two kilometres east of the Adelaide city centre. The data collected from this site from 1990 to 2012 (for studies 2 through 4) were assumed to represent weather conditions across metropolitan Adelaide.

### **3.5 Food safety survey**

The methods, analyses and results for study 1 is described in detail in the published article presented in Chapter 4 and will not be repeated here. Rather, this section will broadly outline the sample design, recruitment process and the analytical approach taken to address the aims of the first study concerning knowledge, preferences and practices with respect to

food safety of *Salmonella* and *Campylobacter* cases, their food consumption patterns and risk perception of foodborne illness in the warm weather.

### **3.5.1. Sample size**

Study participants were identified from the SA Health NIDS database in which all notifications for *Salmonella* and *Campylobacter* cases are recorded. Cases with a laboratory confirmed diagnosis of *Salmonella* or *Campylobacter* infection notified from 1 January to 31 March 2013, and who were resident in SA were invited to participate in the survey to ensure that the sample was geographically representative. There was no restriction on the number of cases selected by age, rather all cases (i.e. adults and children) were invited to participate in the survey. Given that an estimated 600 *Salmonella* and *Campylobacter* cases are notified across the warm season months (annually), and a response rate of 25% to 30% has been reported in other studies that have conducted surveys on food safety [44, 46], this study aimed to recruit 150 participants in order to detect an Odds Ratio (OR) of 1.7 as statistically significant (assuming  $n=150$ ,  $\alpha = 0.05$ , power = 0.80, exposure variable follows standard Normal distribution, and a two-sided test). Thus, the analysis data set with responses from at least 150 *Salmonella* or *Campylobacter* cases was considered to be sufficient to investigate the aims of study 1.

### **3.5.2 Participants and recruitment**

*Salmonella* or *Campylobacter* cases resident of SA and notified to the CDCB with an onset of illness during the warm season of 1 January to 31 March 2013 were invited to participate in the survey. Cases (or parent/guardian if the case was a child) were sent a letter of invitation by the CDCB, which also included the study information sheet, consent form, and questionnaire with a reply paid envelope to the CDCB (Appendix A). In addition to the consent of a parent/guardian, assent was also obtained from children where they had the capacity to do so.

The survey tool was a structured questionnaire (Appendix B) and participants were given three options for completing the survey: on-line, hard copy to be self-administered or via telephone interview. Details of the questionnaire items are expanded upon in Chapter 4. Due to the initial low response rate, a sub-group of the randomly selected cases (30 per month, 90 in total) sent an invitation letter was subsequently contacted by telephone with relevant ethics approval (Appendix C). This ensured a representative sample of cases with respect to notified date of onset of illness.

### **3.5.3 Data analysis**

Bivariate and multivariable logistic regression analyses were used to examine the relationship between food safety practices, behaviour, and knowledge with individual demographic characteristics and socioeconomic status (income, education and level of socioeconomic disadvantage). As outlined more fully below, the outcome variables were derived from responses to questions related to food safety handling practices, knowledge related to food safety and high-risk foods, and preferences for food consumption and eating out, and shopping and receipt of information about food safety. A description of these broad domains covering the questionnaire items is presented in Chapter 4. Age category and gender were included in all of the regression models.

In order to examine the relationship between the demographic and socioeconomic predictors and food safety in warmer weather, the outcome variables were broadly categorised into practices, behaviour, and knowledge. Response options to questions on a 5-point Likert scale were combined to create a binary variable; for example, very safe and safe were combined to make one variable, “safe”, while “unsafe” comprised the response options of neither safe nor unsafe, unsafe and very unsafe. Where appropriate and depending on the type of question, items within these broadly categorised variables were dichotomised into safe and unsafe practices, and good and poor knowledge. The binary variable of “unsafe” was coded as 1 and “safe” was coded as 0. Likewise, this was applied

to the variable related to knowledge whereby “poor” was coded as 1 and “good” was coded as 0.

For some questions relating to food safety knowledge, practices and consumption of high-risk foods, scores for each respondent were summed to derive a total score for personal and food hygiene practices (minimum score 0, maximum score 30); safe food practices (0-25); knowledge on food safety practices (0-25), and consumption (0-16) and knowledge of high-risk foods (0-16). Higher scores were indicative of better knowledge or practice, and lower scores were interpreted to denote poor knowledge and unsafe practices.

In the bivariate logistic regression, analyses were performed for each of the demographic and socioeconomic predictor variables and binary outcome variables related to practices, behaviour, and knowledge. Items showing an association with  $p < 0.25$  significance level were included in the preliminary multivariable logistic regression models. From these preliminary models we selected variables with a significance level  $p < 0.05$  and used backwards elimination in the second stage of multivariable model fitting to arrive at our final statistical models [122]. We evaluated the model fit by calculating the likelihood ratio test and the Pseudo R-squared ( $R^2$ ) statistic. A likelihood ratio that is not significant indicates that the model being tested is a good fit to the data. Models with level of socioeconomic disadvantage were found to have consistently better fit compared to models with levels of income or education, and so results from these models are presented in Chapter 4.

### **3.5.4 Ethics approval**

Ethics approval for the food safety survey was given by the Human Research Ethics Committee of SA Health (HREC/12/SAH/93) (Appendix C). No individual was identifiable in the collected data in this survey, and all data were stored in de-identified format.



## **3.6 Relationship between ambient temperature and *Salmonella* and *Campylobacter* notifications**

### **3.6.1 Definitions**

#### *Exposure*

Daily maximum temperature was selected as the exposure variable, as it measures the highest recorded temperature in the 24 hours following 9am each day and is considered to be a better index of exposure than average and mean minimum temperature. Daily maximum temperature is also consistent with methods used in other studies conducted in SA that have demonstrated an association between maximum temperature and heat-related health outcomes [3, 5, 114].

This study adopted the heatwave definition used in previous heatwave-health associated investigations in SA. A heatwave is defined to have taken place when the daily maximum temperature reaches or surpasses three or more consecutive days of 35°C [3, 5, 114]. As the investigation concerned the relationship of foodborne disease incidence with warm season temperatures and heatwaves, the warm season extended to cover the warm temperature period of 1 October to 31 March for analysis, i.e. two months prior and one month after the southern hemisphere summer months.

#### *Outcome*

The outcome variables were daily counts of *Salmonella* and *Campylobacter* notifications. In communicable disease surveillance datasets, the health outcome measure is typically disease incidence, which is commonly aggregated to weekly or monthly values because many infectious diseases are considered to be rare events in a population [123]. However, in this study we used daily counts which was appropriate as overall reporting counts were not small. Date of onset of illness was used as it is a better estimation of the relationship between temperature and disease incidence than other dates, such as date of notification, and date of specimen test [99].

### **3.6.2 Analysis of temperature in warm seasons**

#### *Study design*

The most common study designs in environmental epidemiology to quantify the human health effects associated with ambient temperature are ecological studies using time-series data. Time-series data is a series of daily counts of the health outcome of interest [124] with observations following a temporal order that are equally spaced at discrete time points [125-127]. In ecological studies disease and exposure are measured in each population with an examination of the relationship between the variable and health outcome under study. Common measures to quantify disease occurrence in populations include incidence and mortality rates [128]. There are limitations and inherent risks of biases in ecological studies, such as association made at a population-level (rather than individual-level) and inadequate control for confounding, but these are offset by possible advantages. Although an ecological study design can preclude investigation of individual-level characteristics, such as age, gender, and genetic factors, many such characteristics are not associated with changes in environmental exposures [124]. The distribution of other individual characteristics, for example smoking, do change over time at a population-level but at a much slower pace, therefore any observed effects of such characteristics can be separated out by a smooth function of time. This approach has been recommended to avoid any residual confounding [124]. Moreover, ecological studies can be effective in finding associations between exposure and health outcomes, which may warrant further investigation [128].

### *Descriptive analyses*

For studies 2 and 4, summary statistics were calculated to provide information about the cases, along with seasonal and long-term trend patterns. Meteorological variables were graphically displayed to identify any patterns over time. At each individual case-level characteristics including age, gender, aggregated postcode of residence, serotype and phage type, and whether cases were linked to an outbreak were summarised using means and standard deviations (for continuously distributed variables) and percentages (for categorical variables). Spearman correlation was calculated to examine the association between daily maximum temperature and *Salmonella* and *Campylobacter* counts, including *Salmonella* serotypes and phage types.

### *Time-series Poisson regression*

The majority of the studies presented in Tables 1 to 4 (Chapter 2) that examined the relationship between temperature and foodborne disease used time-series analysis to predict the expected number of weekly or monthly outcomes as a function of exposure levels [118]. Time-series analyses have been widely used to assess the health effects of short-term changes in ambient temperature and the long-term changes in detecting the early health effects of climate variability. Examples of the latter studies include examination of the health effects of increased ambient temperatures and heatwaves on mortality and morbidity [125, 126].

There are potential methodological and analytical issues to be considered with time-series data [124]. One of the key issues of concern is the need to control for potential confounding variables such as seasonal distribution and long-term trends [124].

Controlling for such variables in the analysis avoids making the assumption about regular patterns and allows for an estimation of the short-term effects of weather on health outcomes [129]. Long-term trends can reflect changes in incidence, changes in health promotion activities, or changes in reporting rates over time, hence the need to adjust for

these factors in the analysis [79]. Time-series regression models also need to account for auto-correlation. This is critical to ensure valid inference and interpretation, as ignoring auto-correlation means that dependence between the values of the time-series is not taken into account, hence the need for precision when estimating auto-correlation [130].

Time-series analysis is also used to model any lag in effect of a climate variable and its impact on the outcome. This is important in the investigation of foodborne disease, as there can be delays between the time of reporting such disease relative to exposure to higher temperatures. An early study on climate variability and food poisoning found a strong relationship with temperature in the preceding month [131]. Thus, it is important to determine if there are any time lags observed between temperature events and foodborne incidence as lags in effects have implications for identification of the source of infection and subsequent prevention. By way of example, it may be animal husbandry and not food handling that is problematic. Sensitivity analysis of different lag times also needs to be conducted to determine which has the best model fit. In our study sensitivity analyses of different lag times up to 28 days were conducted based on the cross-correlation results and from existing knowledge on transmission of *Salmonella* and *Campylobacter* spp. infection. As described in detail in Chapter 5 and 7, we overcame the methodological and analytical issues described above by including long-term trends, seasonality, auto-correlation and lagged effects in the statistical models.

In the studies in this thesis, daily count data were used, and thus we assumed a Poisson distribution [132] for the outcome variable (disease incidence). We also investigated if a negative binomial distribution resulted in a superior model fit compared with a Poisson distribution, to assess the extent of over-dispersion in the data set. For *Salmonella*, we investigated the effect of temperature on overall *Salmonella* counts. In separate analyses, we examined the five most frequently occurring strains of *Salmonella* to see if temperature was differentially associated with different serotypes. We chose the five most frequent

strains for analysis because during the entire thesis study period there were 178 unique *Salmonella* serotypes and phage types reported, with very sparse numbers of cases for many serotypes and phage types. Therefore, with such sparse data it would have been most unlikely to detect any effect of temperature as statistically significant based on number of observations in the study period. Furthermore, the five most frequently observed *Salmonella* serotypes and phage types have been implicated in previous foodborne disease outbreaks [133-136].

In summary, time-series regression analysis that accounts for long-term trends, auto-correlation, over-dispersion, and lag effects was an appropriate framework to address research questions 2 and 4. This approach to quantify the association between warm season temperature with incidence of *Salmonella* and *Campylobacter* infections will be used to determine the best fit model based on goodness of fit test. This is measured by the Pearson chi-square and deviance chi-square, if these calculations are not significant, then the model being tested is a good fit to the data. Seasonal fluctuations are likely to be present in studies examining a temporal relationship; however in the analyses presented here, we overcame this by excluding other seasons and restricting analyses to the warm season (1 October to 31 March). Risk estimates were calculated, representing a percent increase or decrease, in *Salmonella* and *Campylobacter* incidence during warm season temperatures.

#### *Temperature thresholds*

As described earlier in Section 2.4.3, the relationship between temperature and a range of health outcomes has been found to be non-linear, usually taking the functional form of a U, V or J shaped curve [81]. Temperature thresholds are defined as temperatures at which point the risk of health outcomes of interest changes. The change point of the curve, whether it be U, V or J shaped, is considered to be the critical threshold for the exposure-response relationship, and this value can be estimated by several different methods. Some

authors visually inspect plots to estimate the temperature at which there is a change in slope or, more formally, a change point is estimated through statistical modelling [81].

In the studies in this thesis, the exposure-response relationship between *Salmonella* (or serotypes) and *Campylobacter* counts and daily maximum temperature was examined by use of a non-parametric regression lowess (locally weighted scatter plot smooth) smoother at a bandwidth of 0.8 (using 80% of the data). The plots were visually inspected for temperature thresholds. Piecewise linear regression models were then fitted with a single breakpoint at the identified temperature thresholds using the ‘hockey-stick’ `nl` command in Stata. Separate piecewise linear regression models (if appropriate) were fitted to examine the effects of temperature in the warm season on daily *Salmonella* counts, on each of the five serotype counts and on *Campylobacter* counts.

### **3.6.3 Analysis of heatwave effects**

In this study on heatwaves and the incidence of *Salmonella* and *Campylobacter* notifications, Generalized Estimating Equations (GEE) with a Poisson distribution and log-link were used to estimate association between exposure and health outcome. This approach was needed to account for clustering of days within heatwaves.

#### *Descriptive analyses*

For each of studies 3 and 4 (Chapter 6, 7), summary statistics were calculated to provide information about the cases, along with seasonal and long-term trend patterns.

Meteorological variables were graphically displayed to identify any patterns over time. At each individual case-level, characteristics including age, gender, serotype and phage type, and whether cases were linked to an outbreak were summarised using means and standard deviations (for continuously distributed variables) and percentages (for categorical variables).

### *Generalized Estimating Equations*

The GEE approach was developed by Liang and Zeger [137] as a method of analysis that accounts for correlated observations. GEE, an extension of the generalized linear model (GLM), uses a population-averaged method to estimate the average response of the sub-population that shares the same outcome as a function of the predictive variables, which will lead to correct inference about the effects of predictor variables (i.e. the mean structure), even if the assumptions concerning the correlation between observations within a cluster are not correct. Central to the GEE approach is that observations in different clusters are assumed to be independent, but within-cluster correlation can be non-zero [137, 138]. Assumptions about the ‘working correlation’ structure do not affect inference about the mean structure, and as such, GEE is a robust statistical method. GEE was appropriate for the analysis for the longitudinal data in our study. Observations from different years were assumed to be independent, while observations within the same years were correlated. There are several advantages to the GEE approach making it an appropriate choice of method for the analysis in this thesis. As well as providing unbiased standard errors and allowing for misspecification of the correlation structure (assuming the mean model is correctly specified), GEE models also accommodate missing data [137, 138].

As no studies have investigated the effects of heatwaves on *Salmonella* or *Campylobacter* notifications we applied the framework used by D’Ippoliti, Mastrangelo and Son [2, 139, 140]. Since these earlier studies have been published, the GEE approach has been used in other heat-health outcome studies [83, 141-143].

In this thesis the GEE approach was used to model the relationship between daily *Salmonella* counts with daily maximum temperature during heatwaves. Analogous models were then fit to examine the relationship between each of the five *Salmonella* serotypes or *Campylobacter* counts and daily maximum temperature during heatwaves. We also used

GEE models to estimate how *Salmonella* and *Campylobacter* incidence was affected by three heatwave characteristics of intensity (daily maximum temperature during heatwave periods), duration (heatwave length in days) and timing (occurrence in the season e.g. 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>) within the warm seasons. Each day in the study period was categorised as a “heatwave” or “non-heatwave” day, and this was used as the exposure variable to estimate the effect of heatwaves on incidence of *Salmonella* and *Campylobacter* notifications. The GEE model was fitted separately for each heatwave characteristic (i.e. intensity, duration and timing). Every day in a heatwave event was assigned a cluster, and every day within that cluster was identified with a separate indexing variable. Given that the time-series data were unbalanced, in that for most of the clusters there were no previous observations because they were not part of a heatwave and there was no logical ordering to the observations within a cluster, an exchangeable working correlation matrix was specified. Risk estimates were calculated, representing a percent increase or decrease, in *Salmonella* and *Campylobacter* counts during heatwaves with comparison made to non-heatwave days during the summer season.

#### *Distributed Lag Non-Linear Model*

More recently, Distributed Lag Non-Linear models (DLNMs) have been used in environmental epidemiology studies. Such models can be used to examine non-linear exposure-response associations in time-series data that are further complicated by lagged effects of the exposure (i.e. temperature) on the health outcomes [144]. The approach is used to estimate the effects of temperature and lags from one model. It is flexible as a more complex temporal structure for the lag effects can be modelled allowing for non-linear main effects of temperature [145]. DLNMs can be used to model the effects of temperature on the number of cases along a two dimensional axis of temperature and lag. Natural cubic splines are derived allowing estimation of the effects of temperature with a



range of possible time lags in the effects of temperature [144]. A three-dimensional graph plots the RR along both temperature and time.

DLNMs are now widely used in heat-health studies to examine non-linear and lagged effects of temperature simultaneously related to a range of health outcomes [146-149].

Very few studies have used these models to examine the relationship between temperature and infectious gastroenteritis. As presented in Table 1 and 4 of Chapter 2, only one study used DLNM to examine the relationship between temperature and salmonellosis [93], and the other study using DLNM examined the relationship between heatwaves and infectious gastroenteritis [115]. The DLNM approach that we have used in this study to examine the relationship between heatwaves and *Salmonella* infection is relatively novel and provides a useful framework for assessing these associations simultaneously accounting for non-linear effects of temperature and lagged effects over time.

A significance level of 0.05 was accepted for all statistical tests. Analyses were conducted using StataSE 13 (StataCorp LP, College Station, Texas) or R version 3.1.1 (R Foundation for Statistical Computing, <http://cran.rproject.org/>). The latter was used to fit the DLNM models with the ‘dlnm’ package.

#### **3.6.4. Ethics approval**

Ethics approval for the analysis of *Salmonella* and *Campylobacter* notification data was given by the Human Research Ethics Committees of The University of Adelaide (H-202-2011) and SA Health (463/07/2014) (Appendix D). No individual was identifiable in any data supplied by SA Health, nor in resulting data sets nor presentation of results.

In this thesis, time-series Poisson regression models were combined with DLNM models to investigate if there was a delayed effect of heatwave intensity (daily maximum temperature during heatwaves) on daily *Salmonella* and serotype notifications. This model was not applied to the heatwave and *Campylobacter* study presented in Chapter 7 as a relationship

with temperature in the warm seasons and daily counts was not found. In the following Chapters 4 through 7, I present the results of the four studies that comprise this thesis as publications accepted by various journals.

# **Chapter 4 Study 1: Factors influencing knowledge, food safety practices and food preferences during warm weather of *Salmonella* and *Campylobacter* cases in South Australia**

---

## **4.1 Preface**

This chapter contains the first of four articles contributing to this thesis. This article has been published in *Foodborne Pathogens and Disease* and examines whether food safety handling and storage, behaviours related to shopping and eating out, and preferences for eating certain high-risk foods for *Salmonella* and *Campylobacter* infection, is influenced by warm weather. The study also examined whether knowledge about food safety, practices and preferences was determined by socioeconomic status. In addition, participants were asked about their preferred mode for receiving information about food safety in warm weather which is important for foodborne disease prevention.

As no study has specifically investigated whether warm weather has an indirect impact on social and behavioural factors related to food preferences and food safety, this article provides the evidence base for public health interventions related to the food industry around regulatory measures, monitoring and enforcement of policy for foodborne disease prevention. In addition, the findings point to a need for community awareness and education programs directed at personal behaviour related to food safety practices in the domestic household.

## 4.2 Publication

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Factors influencing knowledge, food safety practices and food preferences during warm weather of *Salmonella* and *Campylobacter* cases in South Australia. *Foodborne Pathogens Disease*. 2017;14(3):125-131.

### Statement of Authorship

Title of Paper	Factors influencing knowledge, food safety practices and food preferences during warm weather of <i>Salmonella</i> and <i>Campylobacter</i> cases in South Australia
Publication Status	<input checked="" type="checkbox"/> Published <input type="checkbox"/> Accepted for Publication <input type="checkbox"/> Submitted for Publication <input type="checkbox"/> Unpublished and Unsubmitted work written in manuscript style
Publication Details	Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Factors influencing knowledge, food safety practices and food preferences during warm weather of <i>Salmonella</i> and <i>Campylobacter</i> cases in South Australia. <i>Foodborne Pathogens Disease</i> , 2016, 14 (3), 125-131.

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Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

- i. the candidate's stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Signature		Date	18-05-17

Milazzo, A., Giles, L.C., Zhang, Y., Koehler, A.P., Hiller, J.E. and Bi, P. (2017). Factors influencing knowledge, food safety practices and food preferences during warm weather of Salmonella and Campylobacter cases in South Australia. *Foodborne Pathogens and Disease*, 14(3), 125–131.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

<https://doi.org/10.1089/fpd.2016.2201>

# **Chapter 5 Study 2: The effect of temperature on different *Salmonella* serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia**

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## **5.1 Preface**

This chapter contains the second article contributing to this thesis published in *Epidemiology and Infection*, and examines whether warm season temperature is associated with an increased risk of daily *Salmonella* notifications. The analysis was taken one step further by assessing the relationship with temperature and the five top *Salmonella* serotypes and/or phage types reported in Adelaide during the warm seasons. The aim of this chapter is to contribute to the limited evidence regarding the effects of warm temperature and overall *Salmonella* notifications and serotypes in Adelaide with a temperate climate. In this study temperature thresholds were identified revealing an increase in risk of infection at higher temperatures for certain *Salmonella* serotypes and their phage types, which are commonly isolated in Adelaide, but also nationally. As very few studies have investigated whether *Salmonella* strains are differentially affected by temperature, this article addresses an important research gap which may have policy and public health practice implications.

## 5.2 Publication

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effect of temperature on different *Salmonella* serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia. *Epidemiology and Infection*. 2016;144:1231-1240.

### Statement of Authorship

Title of Paper	The effect of temperature on different <i>Salmonella</i> serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia
Publication Status	<input checked="" type="checkbox"/> Published <input type="checkbox"/> Accepted for Publication <input type="checkbox"/> Submitted for Publication <input type="checkbox"/> Unpublished and Unsubmitted work written in manuscript style
Publication Details	Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effect of temperature on different <i>Salmonella</i> serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia. <i>Epidemiology and Infection</i> , 2016, 144 (6), 1231-1240

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Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.				
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- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Associate Professor Lynne Giles				
Contribution to the Paper	Designed the statistical framework, contributed to the interpretation of the results and reviewed the manuscript.				
Signature	<table border="1" style="width: 100%;"> <tr> <td style="width: 80%;"></td> <td style="width: 20%;">Date</td> </tr> <tr> <td></td> <td>16/5/17</td> </tr> </table>		Date		16/5/17
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Name of Co-Author	Dr Ying Zhang				
Contribution to the Paper	Contributed to the interpretation of the results and reviewed the manuscript.				
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Name of Co-Author	Associate Professor Ann Koehler				
Contribution to the Paper	Contributed to the interpretation of results and reviewed the manuscript.				
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	18-5-17				

Milazzo, A., Giles, L.C., Zhang, Y., and Koehler, A.P. (2016). The effect of temperature on different Salmonella serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia. *Epidemiology & Infection*, 144(6), 1231-1240.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

<https://doi.org/10.1017/S0950268815002587>



# Chapter 6 Study 3: Heatwaves differentially affect risk of *Salmonella* serotypes

---

## 6.1 Preface

This chapter contains the third article contributing to this thesis published in *Journal of Infection*, and examines whether heatwaves are associated with an increased incidence of daily *Salmonella* notifications, including different serotypes and phage types. This study revealed an association between heatwaves, overall *Salmonella* notifications and certain serotypes and their phage types. These *Salmonella* strains are commonly reported in SA and Australia, and are linked to animal and food sources, suggesting that heatwaves may play an important role in transmission of *Salmonella* infection through food contamination. As no Australian study has investigated the effects of heatwaves on *Salmonella* and specific strains, this article provides critical information on possible transmission pathways and the role of the environment, specifically higher temperatures with duration, and an increase in risk of salmonellosis during heatwaves. These findings will contribute to policy recommendations and highlights the opportunity for further research in this area.

## 6.2 Publication

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Heatwaves differentially affect risk of *Salmonella* serotypes. *Journal of Infection*. 2016;73:231-240.

### Statement of Authorship

Title of Paper	Do heatwaves differentially affect risk of <i>Salmonella</i> serotypes
Publication Status	<input checked="" type="checkbox"/> Published <input type="checkbox"/> Accepted for Publication <input type="checkbox"/> Submitted for Publication <input type="checkbox"/> Unpublished and Unsubmitted work written in manuscript style
Publication Details	Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. Do heatwaves differentially affect risk of <i>Salmonella</i> serotypes. <i>Journal of Infection</i> , 2016, 73, 231-240.

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## Heatwaves differentially affect risk of *Salmonella* serotypes



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Accepted 20 April 2016

Available online 15 June 2016

### KEYWORDS

Heatwaves;  
Temperature;  
Climate change;  
Salmonellosis;  
*Salmonella* serotypes;  
Generalised estimating equations;  
Distributed lag non-linear model

**Summary** *Objectives:* Given increasing frequency of heatwaves and growing public health concerns associated with foodborne disease, we examined the relationship between heatwaves and salmonellosis in Adelaide, Australia.

*Methods:* Poisson regression analysis with Generalised Estimating Equations was used to estimate the effect of heatwaves and the impact of intensity, duration and timing on salmonellosis and specific serotypes notified from 1990 to 2012. Distributed lag non-linear models were applied to assess the non-linear and delayed effects of temperature during heatwaves on *Salmonella* cases.

*Results:* *Salmonella typhimurium* PT135 notifications were sensitive to the effects of heatwaves with a twofold (IRR 2.08, 95% CI 1.14–3.79) increase in cases relative to non-heatwave days. Heatwave intensity had a significant effect on daily counts of overall salmonellosis with a 34% increase in risk of infection (IRR 1.34, 95% CI 1.01–1.78) at >41 °C. The effects of temperature during heatwaves on *Salmonella* cases and serotypes were found at lags of up to 14 days.

*Conclusion:* This study confirms heatwaves have a significant effect on *Salmonella* cases, and for the first time, identifies its impact on specific serotypes and phage types. These findings will contribute to the understanding of the impact of heatwaves on salmonellosis and provide insights that could mitigate their impact.

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## Introduction

Human *Salmonella* infection is a significant global public health problem with an estimated 93.8 million cases per year, of which 80.3 million are foodborne.<sup>1</sup> In Australia with a population of approximately 22 million, the incidence of infectious gastroenteritis attributed to foodborne disease is estimated to be 4.1 million cases per year.<sup>2</sup> *Salmonella* is a common cause of foodborne illness in humans and is a frequently reported bacterial aetiological agent in Australia.<sup>3</sup> Bacterial infectious agents such as *Salmonella* that cause foodborne disease are sensitive to temperature variability, and in warmer temperatures the rate of replication is high, with *Salmonella* proliferation occurring more rapidly in animal guts and food.<sup>4</sup>

Adelaide, the capital city of South Australia (SA) experiences a Mediterranean climate with mild winters and hot, dry summers. Heatwaves in SA have increased in frequency since 1950.<sup>5</sup> If the effects of climate change continue to accumulate, coupled with the prediction of increasing heatwave events in Australia and worldwide, then the increase in risk for foodborne disease, in particular salmonellosis is considerable. A relationship between warmer ambient temperature and salmonellosis has been previously studied.<sup>6–17</sup> These studies found increases of 1–15% of cases per 1 °C rise in temperature.<sup>13</sup>

Nonetheless, there are no reported studies on the effect of heatwaves on incidence of *Salmonella* notifications which is important given that disease burden could be greater than that associated with temperature alone, and infection from *Salmonella* is preventable. The aim of this study was to examine if there is a relationship between heatwaves and number of *Salmonella* cases in Adelaide, and to assess the impact of heatwaves on specific *Salmonella* serotypes.

## Methods

### Data sources

Daily laboratory confirmed salmonellosis cases resident within the Adelaide metropolitan region and notified between 1 January 1990 and 31 December 2012 were obtained from the SA Health Department's notifiable disease surveillance system. Surveillance of people diagnosed with *Salmonella* infection relies on doctors and laboratories to notify suspected and confirmed cases as part of their legal duty. Information extracted for notified cases included date of onset of illness and demographic characteristics. *Salmonella* serotype identified for each case was extracted from the same surveillance system which reports data on *Salmonella* serotypes and phage types. The use of laboratory methods in SA to serotype and phage type *Salmonella* isolates have been consistent over the study period.

Climatic information was obtained from an Australian Bureau of Meteorology (BOM) weather monitoring station close to the Adelaide city centre. Daily maximum temperature ( $T_{\max}$ ) in degrees Celsius (°C) and rainfall in millimetres (mm) from 1990 to 2012 were extracted. Recordings from this station, according to BOM, are

representative of weather conditions across the metropolitan region of Adelaide.<sup>16,18–21</sup>

### Heatwave definition and characteristics

A heatwave definition was defined as a period where the daily  $T_{\max}$  reaches or exceeds three or more consecutive days of 35 °C. We selected this definition as it has demonstrated an effect on human health in other SA studies examining the relationship between heatwaves and morbidity and mortality outcomes.<sup>18–20</sup> The analysis dataset was restricted to the warm season from 1 October to 31 March, so as to control for the potential confounding effects of seasonal variation.<sup>7</sup>

Heatwaves are extended periods of unusually hot weather and their impact on mortality<sup>22,23</sup> and morbidity<sup>18,24</sup> is well established. However, there is some uncertainty about the characteristics that make heatwaves hazardous to human health. Characteristics such as intensity and duration should be considered.<sup>25</sup> In this study, the role of heatwave intensity, duration and timing on daily *Salmonella* notifications and the effect on different serotypes were examined. Intensity was defined as the daily  $T_{\max}$  of  $\geq 35$  °C recorded during heatwaves, heatwave duration was the number of days in each episode, and timing was the first, second, or third and so on heatwave of the season.

### Statistical analysis

Poisson regression models, assuming an exchangeable correlation structure within each cluster of heatwave days, were fitted using Generalised Estimating Equations (GEE) to examine the effect of heatwaves on daily *Salmonella* cases and number of cases of *Salmonella* specific serotypes during heatwaves compared with non-heatwave periods. Specific serotypes and phage types were selected for further analysis based on the five ranked with the highest frequency over the study period. We used the Quasilielihood under the independence model criterion (QIC) to select the best working correlation structure. In the case of over-dispersion a negative binomial model was fitted.

As expected for Adelaide there was little rainfall recorded during heatwave periods and rainfall was not included in the models. Relative humidity was excluded because Adelaide experiences dry, hot weather during the warmer months, therefore humidity is unlikely to confound the relationship with heatwaves. Findings from another study on temperature and salmonellosis conducted in Adelaide found relative humidity was not significant, and so it was not included in their statistical models.<sup>16,21</sup> Day of the week was included in the statistical models as a categorical variable, and public holidays were controlled for with an indicator variable. Variables reflecting linear and quadratic effects of year were included to adjust for long term trends and to allow for a non-linear relationship between counts and time.

Cases with *Salmonella* infection linked to foodborne outbreaks in which a common source had been identified and/or observed numbers of cases exceeded the expected

number for the time period were identified from the SA Health Department's notifiable disease surveillance system. These cases were excluded from the analyses, as the relationship of climate conditions may be different for those with a common exposure compared to sporadic cases with no identified source of infection.<sup>10,16,26</sup>

### Heatwave characteristics

To estimate the overall effect of heatwaves a binary variable (heatwave and non-heatwave days) was included. We used a categorical variable to identify heatwave days in order to examine the day which produced a greater risk of *Salmonella* infection. Intensity was examined by daily  $T_{max}$  within heatwaves and treated as a categorical variable in the Poisson model with four temperature ranges (35–36.9 °C, 37–38.9 °C, 39–40.9 °C,  $\geq 41$  °C). Duration was defined as three, four and five or more days. An alternative definition was used to examine the effect of short (three days) compared to long duration (four or more days). We considered two aspects of timing. First, timing was defined by the first, second and third heatwave event within each warm season denoting the order of occurrence. Second, timing differed by whether the heatwave event occurred in the early part of the warm season (October–December) or later (January–March).

Separate models were fitted to examine the effects of each heatwave characteristic on daily *Salmonella* counts. The same analyses were repeated for each of the five serotype counts. Incidence rate ratios (IRR) with 95% confidence intervals (CI) are reported with results interpreted as percentage (%) change in the number of daily *Salmonella* counts during heatwave periods compared with non-heatwave periods.

### Lag effects

Distributed lag non-linear models (DLNMs) were separately fitted to investigate if there was a delayed effect of  $T_{max}$  during heatwaves on daily *Salmonella* and serotype notifications.<sup>27,28</sup> A previous study in SA on salmonellosis and temperature reported a lag of two weeks and based on these results a lag of up to 14 days was selected for this study.<sup>16</sup> We used natural cubic splines with three degrees of freedom (df) for  $T_{max}$  during heatwaves and natural cubic splines with three or four df (depending on serotype) for lags of 0–3, 0–7, 0–10, and 0–14 days. In the DLNMs models  $T_{max}$  during heatwaves as a continuous variable reflected intensity. We plotted lag-response results at mean  $T_{max}$  within heatwaves and three-dimensional plots for the effects of temperature in heatwaves at all lag days. We controlled for the same variables as per the GEE models. The Akaike Information Criterion (AIC) was used to select the best model based on the lowest AIC values. Results are reported from the DLNM analyses as Relative Risks (RR) and 95% CI. Sensitivity analyses were used to evaluate df for heatwave intensity (daily  $T_{max}$  as a continuous variable) and df for lags from 0 to 14 days.

A significance level of 0.05 was accepted for all statistical tests. Analyses were conducted using StataSE 13 (StataCorp LP, College Station, Texas) or R version 3.1.1

(R Foundation for Statistical Computing, <http://cran.r-project.org/>). The latter was used to fit the DLNM models with the 'dlnm' package.

### Ethics statement

All data analysed were non-identifiable with ethics approval given by the Human Research Ethics Committees of The University of Adelaide (H-202-2011) and the SA Department for Health and Ageing (463/07/2014).

## Results

### Descriptive

A total of 7845 *Salmonella* cases (excluding outbreak cases) were reported in the study period from 1990 to 2012, 4412 of which had an illness onset date in the warm season of October–March. Of the 4412 cases, 51% were female and 49% were male. The 1–9 (26%) and 20–39 (25%) year age groups had the highest percentage of cases, followed by 40–59 (16%), 60+ (12%), 10–19 (10%) and <1 year of age (9%). Of the 4412 *Salmonella* cases reported in the warm season, 1217 (27.5%) were included in the top five serotype and phage types in our analyses. There were 178 unique *Salmonella* serotypes reported across the study period, with the five highest in frequency during the study period warm season being: *Salmonella enterica* serovar Typhimurium phage type 9 (*Salmonella typhimurium* PT9) (n = 422), *Salmonella infantis* (*S. infantis*) (n = 229), *S. typhimurium* PT108 (n = 209) is also typed as *S. typhimurium* PT170 in other jurisdictions, *S. typhimurium* PT44 (n = 179) and *S. typhimurium* PT135 (n = 178). Approximately 60% of the total numbers of serotype cases were notified in the warm season.

Table 1 presents summary statistics for temperature. The mean daily  $T_{max}$  in Adelaide was 38.4 °C (Standard deviation (SD) = 2.22) during heatwaves. A total of 50 heatwave events (comprising 213 days of three or more consecutive days met the heatwave definition) and was recorded in 50 separate events across the study period. In 2009, a nine day heatwave (with temperature above 40 °C on six consecutive days) was reported. The highest  $T_{max}$  recorded during any heatwave was 45.7 °C. Duration of heatwaves ranged from three to 15 days with a mean of 3.17 (SD = 2.40) days. No heatwaves were recorded outside of the warm season and none were recorded in 1990, 1996 and 2005.

### Effect of heatwaves and heatwave characteristics on *Salmonella*

Fig. 1 illustrates the overall effect of heatwaves for all notified *Salmonella* cases and serotypes. The effect on daily *Salmonella* counts compared with those on non-heatwave days was not significant (IRR 1.02, 95% CI 0.84–1.25). Table 2 summarises the heatwave effect estimates. Heatwave intensity rather than duration had a greater impact on daily *Salmonella* infections. A 34% increase (IRR 1.34, 95% CI 1.01–1.78) in *Salmonella* cases was estimated if

**Table 1** Daily maximum temperature ( $T_{\max}$ ) by season and percentile, 1990 to 2012, Adelaide, South Australia.

Time period	Maximum temperature ( $T_{\max}$ )							
	Mean	5th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile	99th percentile
1990–2012 <sup>a</sup>	22.3 °C	14.1 °C	17 °C	21.1 °C	26.6 °C	32.3 °C	35.3 °C	39.8 °C
Cool <sup>b</sup>	18.2 °C	13.4 °C	15.3 °C	17.2 °C	20.2 °C	24.1 °C	26.4 °C	30.6 °C
Warm <sup>c</sup>	26.5 °C	17.8 °C	21.9 °C	25.7 °C	31 °C	35.3 °C	37.7 °C	41.2 °C
Heatwaves <sup>d</sup>	38.4 °C	35.4 °C	36.6 °C	38.3 °C	39.8 °C	41.5 °C	42.9 °C	43.9 °C

<sup>a</sup> *Salmonella* cases (n = 7845) notified in the study period.

<sup>b</sup> *Salmonella* cases (n = 3433) notified in the cool season (April–September).

<sup>c</sup> *Salmonella* cases (n = 4412) notified in the warm season (October–March).

<sup>d</sup> *Salmonella* cases (n = 238) notified during heatwaves.

$T_{\max}$  was  $\geq 41$  °C (compared to temperature ranges between 35–36.9 °C, 37–38.9 °C and 39–40.9 °C). *Salmonella* cases were less frequent in the early months of the warm season compared to the later months.

### Effect of heatwaves and heatwave characteristics on *Salmonella* serotypes

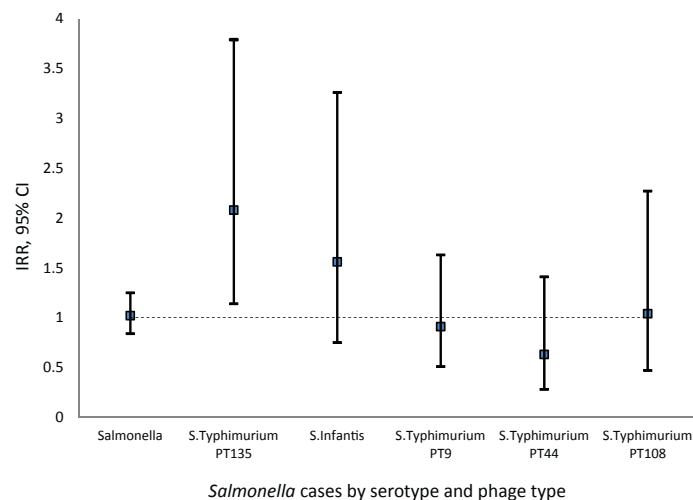
The effect of heatwaves on daily counts was only significant for *S. typhimurium* PT135 as depicted in Fig. 1, such that the risk doubled during heatwaves (IRR 2.08, 95% CI 1.14–3.79). As shown in Table 2, there was a twofold increase in risk on day three (IRR 2.09, 95% CI 1.04–4.20) and a greater increase on day five (IRR 2.72, 95% CI 1.20–6.12) for *S. typhimurium* PT135 relative to non-heatwave days.

Heatwave intensity increased the risk of *S. typhimurium* PT135 by almost threefold (IRR 2.96, 95% CI 1.21–7.24) within  $T_{\max}$  range of 39–40.9 °C. Short duration increased

the risk twofold for *S. typhimurium* PT135 (IRR 2.10, 95% CI 1.05–4.20) and duration by length of days had effects at four (IRR 3.30, 95% CI 1.34–8.13) and five days (IRR 2.47, 95% CI 1.04–5.88). Four day duration increased *S. infantis* notifications close to threefold (IRR 2.84, 95% CI 1.26–6.41). An increase in *S. typhimurium* PT135 infections was estimated with the second heatwave event in the season (IRR 2.53, 95% CI 1.07–6.01), and a much higher risk in the third (IRR 4.24, 95% CI 2.19–8.22). The number of cases was lower in the early months of the warm season compared to the later months for all serotypes and phage types, with the exception of a non-significant effect estimate for *S. typhimurium* PT44.

### Lag effects

Fig. 2 presents the lag effects up to 14 days of  $T_{\max}$  during heatwaves on *Salmonella* and serotype cases and Fig. 3 shows the three-dimensional plots for significant RR for *Salmonella* and two of the serotypes. As shown in Fig. 2A, the



**Figure 1** Effect estimates of heatwaves for all notified *Salmonella* cases and specific serotype and phage types, 1990–2012, Adelaide, South Australia.

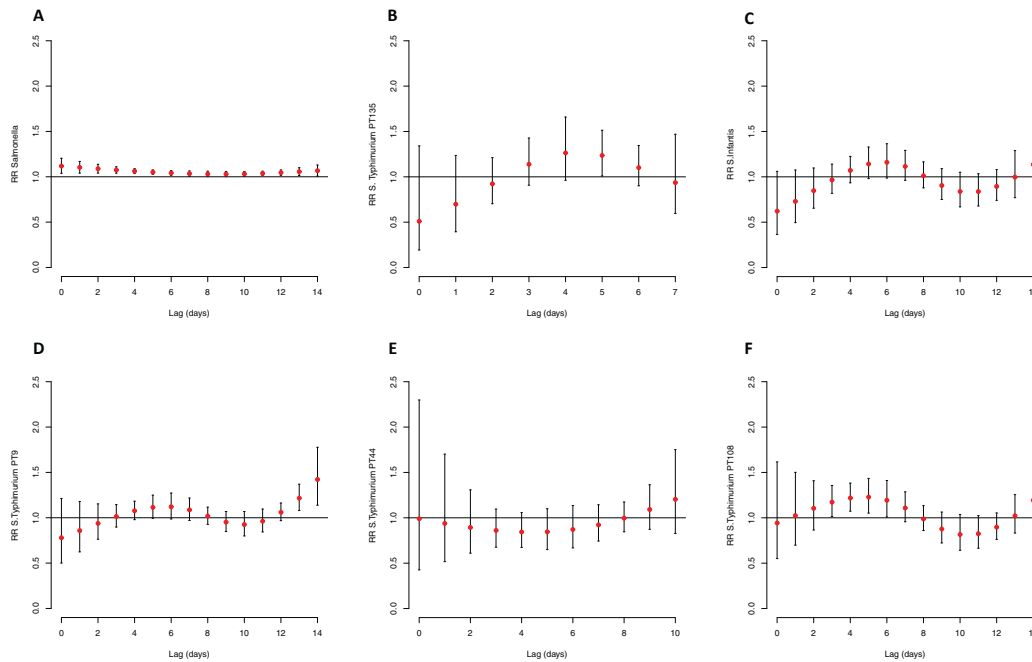
**Table 2** Effect estimates of heatwave characteristics on daily *Salmonella* cases and specific serotypes and phage types.

Heatwave characteristic	<i>Salmonella</i> IRR (95% CI)	<i>p</i>	<i>S. typhimurium</i> PT135 IRR (95% CI)	<i>p</i>	<i>S. infantis</i> IRR (95% CI)	<i>p</i>	<i>S. ypphimurium</i> PT9 IRR (95% CI)	<i>p</i>	<i>S. typhimurium</i> PT44 IRR (95% CI)	<i>p</i>	<i>S. typhimurium</i> PT108 IRR (95% CI)	<i>p</i>
<b>Heatwave</b>	1.02 (0.84, 1.25)	0.77	2.08 (1.14, 3.79)	0.01	1.56 (0.75, 3.26)	0.23	0.91 (0.51, 1.63)	0.76	0.63 (0.28, 1.41)	0.26	1.04 (0.47, 2.27)	0.91
<b>Day of heatwave</b>												
Day 3	1.05 (0.85, 1.29)	0.63	2.09 (1.04, 4.20)	0.03	2.02 (0.95, 4.29)	<0.01 <sup>a</sup>	0.87 (0.49, 1.54)	0.65	0.63 (0.25, 1.61)	0.34	0.70 (0.30, 1.64)	0.42
Day 4	0.94 (0.63, 1.41)	0.79	1.74 (0.57, 5.24)	0.32	0.57 (0.04, 6.55)	0.65 <sup>a</sup>	0.95 (0.35, 2.57)	0.92	0.54 (0.08, 3.64)	0.52	2.02 (0.69, 5.90)	0.19
Day 5	0.96 (0.65, 1.42)	0.86	2.72 (1.20, 6.12)	0.01	0.28 (0.00, 30.62)	0.60 <sup>a</sup>	1.18 (0.47, 3.00)	0.71	0.81 (0.23, 2.80)	0.74	1.75 (0.54, 5.64)	0.34
<b>Duration</b>												
Short	1.05 (0.85, 1.29)	0.63	2.10 (1.05, 4.20)	0.03	2.01 (0.95, 4.27)	0.06	0.87 (0.49, 1.54)	0.65	0.63 (0.25, 1.61)	0.34	0.70 (0.30, 1.64)	0.42
Long	0.95 (0.66, 1.36)	0.79	2.05 (0.77, 5.40)	0.14	0.40 (0.02, 6.21)	0.51	1.04 (0.43, 2.49)	0.92	0.63 (0.19, 2.06)	0.45	1.91 (0.72, 5.04)	0.18
<b>Duration by length</b>												
3 days	0.93 (0.68, 1.29)	0.70	0.76 (0.20, 2.90)	0.69	1.03 (0.15, 7.04)	0.97	1.09 (0.57, 2.07)	0.77	0.37 (0.50, 2.50)	0.31	0.66 (0.18, 2.33)	0.52
4 days	1.20 (0.86, 1.67)	0.27	3.30 (1.34, 8.13)	<0.01	2.84 (1.26, 6.41)	0.01	0.71 (0.29, 1.69)	0.44	1.08 (0.44, 2.64)	0.85	0.62 (0.18, 2.17)	0.46
5 days	0.96 (0.66, 1.38)	0.83	2.47 (1.04, 5.88)	0.04	0.99 (0.37, 2.65)	0.99	0.97 (0.28, 3.30)	0.96	0.46 (0.08, 2.49)	0.36	1.82 (0.61, 5.42)	0.27
<b>Timing by order of occurrence in a season</b>												
1st heatwave	1.00 (0.74, 1.34)	0.99	0.31 (0.0, 2.2)	0.24	2.01 (0.68, 5.97)	0.20	1.13 (0.44, 2.86)	0.79	0.54 (0.14, 2.01)	0.35	2.07 (0.87, 4.92)	0.09
2nd heatwave	1.00 (0.77, 1.29)	0.97	2.53 (1.07, 6.01)	0.03	0.64 (0.09, 4.41)	0.65	1.11 (0.50, 2.44)	0.79	0.38 (0.06, 2.16)	0.28	0.45 (0.15, 1.40)	0.17
3rd heatwave	1.08 (0.70, 1.67)	0.70	4.24 (2.19, 8.22)	<0.01	1.86 (0.66, 5.21)	0.23	0.49 (0.17, 1.39)	0.18	1.00 (0.35, 2.87)	0.99	<sup>c</sup>	<sup>c</sup>
<b>Timing by months in season</b>												
Early	0.68 (0.64, 0.73)	<0.01	0.57 (0.4, 0.8)	<0.01	0.44 (0.33, 0.58)	<0.01	0.37 (0.29, 0.47)	<0.01	0.87 (0.60, 1.25)	0.47	0.55 (0.40, 0.77)	<0.01
<b>Intensity by temperature range</b>												
35–36.9 °C	0.93 (0.64, 1.35)	0.71	1.30 (0.41, 4.06)	0.64	1.93 (0.54, 6.87)	0.30	1.06 (0.40, 2.81)	0.89	0.93 (0.63, 1.35)	0.71	0.33 (0.04, 2.77)	0.31
37–38.9 °C	0.97 (0.68, 1.38)	0.87	2.34 (0.85, 6.44)	0.09	1.96 (0.80, 4.75)	0.13	0.83 (0.31, 2.22)	0.71	0.98 (0.69, 1.39)	0.92	0.57 (0.14, 2.33)	0.44
39–40.9 °C	0.99 (0.74, 1.33)	0.98	2.96 (1.21, 7.24)	0.01	1.11 (0.28, 4.29)	0.87	0.66 (0.22, 1.92)	0.45	1.14 (0.91, 1.42)	0.24	1.88 (0.62, 5.63)	0.25
≥41 °C	1.34 (1.01, 1.78)	0.04	1.74 (0.60–5.01)	0.30	0.70 (0.09, 5.05)	0.72	1.15 (0.60, 2.19)	0.65	<sup>b</sup>	<sup>b</sup>	2.21 (0.83, 5.90)	0.11

Incidence Rate Ratio (IRR), 95% Confidence Interval (CI), *p*-value (0.05 significance level).

Adjusted for seasonality (warm season), long term trends, day of the week (reference day is Sunday) and public holidays. The reference group are non-heatwave days.

<sup>a</sup> *S. infantis* – re-categorised day of increased risk and fitted to the model.<sup>b</sup> *S. typhimurium* PT44-intensity by temperature range – a variable with three levels was fitted to the model.<sup>c</sup> *S. typhimurium* PT108 – timing by order of occurrence – a variable with two levels was fitted to the model.



**Figure 2** Relative risks of daily *Salmonella* and serotype and phage type counts at 38.4 °C (mean  $T_{\max}$  during heatwaves), using a natural cubic spline–natural cubic spline DLNM with 3 df natural cubic spline for  $T_{\max}$  and 3 df for *Salmonella* (A), *S. typhimurium* PT135 (B), *S. typhimurium* PT44 (E) or 4 df for *S. infantis* (C), *S. typhimurium* PT9 (D), *S. typhimurium* PT108 (F) for lag days, 1990–2012, Adelaide, South Australia.

greatest effect of  $T_{\max}$  during heatwaves on overall *Salmonella* cases was at day-0 lag (at 38.4 °C, RR 1.12, 95% CI 1.04–1.20) and the effect remained elevated up to day-14 lag (at 38.4 °C, RR 1.07, 95% CI 1.01–1.13). Lagged effects of  $T_{\max}$  during heatwaves decreased over time and increased with higher temperature (Fig. 3A). The effects of  $T_{\max}$  during heatwaves on *S. typhimurium* PT44 (Fig. 2E) and *S. infantis* (Fig. 2C) cases over lags of 0–14 days were not significant and marginally significant at day-5 lag for *S. typhimurium* PT135 cases (Fig. 2B). The effect of temperature during heatwaves on *S. typhimurium* PT108 notifications was elevated between day-3 (at 38.4 °C, RR 1.17, 95% CI 1.01–1.36) and day-6 lag (at 38.4 °C, RR 1.19, 95% CI 1.01–1.41) (Fig. 2F). As demonstrated in Fig. 3C, lagged effects on *S. typhimurium* PT108 decreased over time and increased with higher temperature. The effect of  $T_{\max}$  during heatwaves on *S. typhimurium* PT9 cases was elevated between four and six days, and greatest at day-14 lag (at 38.4 °C, RR 1.42, 95% CI 1.14–1.78 (Figs. 2D and 3B).

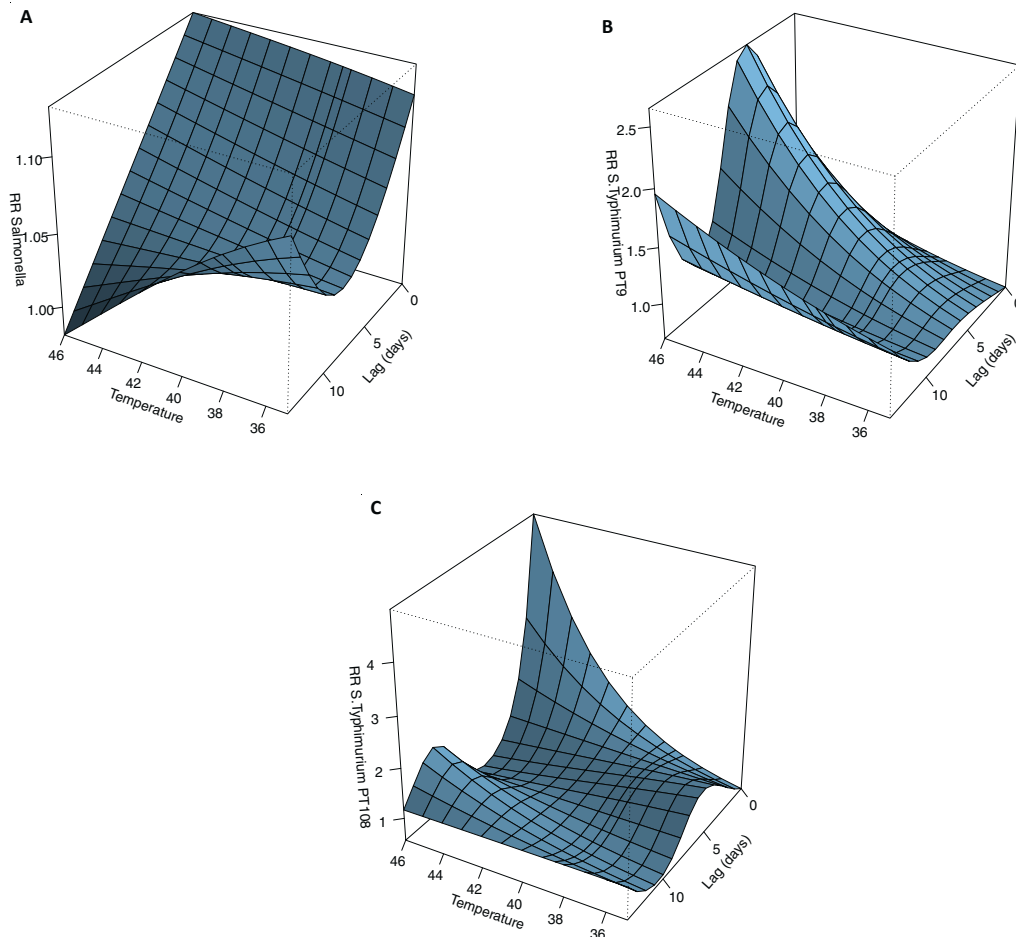
## Discussion

To our best knowledge, this study, for the first time, reports the effect of heatwaves and the role of heatwave intensity,

duration and timing on daily *Salmonella* counts and on different strains. Our findings indicate that higher intensity increases the risk of infection, and that of specific serotypes and phage types. This association is biologically plausible because *Salmonella* growth occurs between 5.2 and 46.2 °C, and within an ideal temperature range of 35–43 °C.<sup>3</sup>

Heat wave duration of four days had a pronounced effect on *S. typhimurium* PT135 and *S. infantis* infection. Our findings are congruent with the results from studies examining the effects and characteristics of heatwaves on enteric infections, but not salmonellosis. Intensity (above 99th percentile) and duration (three days) were associated with hospital emergency department visits for childhood diarrhoea,<sup>29</sup> and hospital admissions for infectious gastroenteritis increased by 4.7% with every additional day in a heatwave.<sup>30</sup> In our study the effect of heatwaves on overall salmonellosis increased by 34% if  $T_{\max}$  was  $\geq 41$  °C. As well, day three and five of a heatwave, and subsequent heatwave events after the first in a warm season, increased the number of *S. typhimurium* PT135 notifications. This could in part be explained by the accumulated effects of  $T_{\max}$  during heatwaves on different stages of food processing, as we found an increase in salmonellosis cases persisted up to 14 days at high temperatures. A better understanding of the likely mechanisms on the effects of heatwaves on





**Figure 3** Three-dimensional plots for risk of *Salmonella* (A), *S. typhimurium* PT9 (B) and *S. typhimurium* PT108 (C) infection by  $T_{\max}$  during heatwaves and lag days 0–14, 1990–2012, Adelaide, South Australia (Temperature =  $T_{\max}$  during heatwaves).

salmonellosis infection is needed so that public health messages can be targeted most effectively to those at greatest risk.

Our study has provided evidence that *Salmonella* serotypes are sensitive to the effects of heatwaves. This is important because not all *Salmonella* serotypes are pathogenic and cause human infection; there are different pathways for transmission<sup>15</sup> and the relationship with temperature is not well established. Previous studies found that the effect of temperature on incidence of *Salmonella* serotypes was statistically significant for *S. typhimurium* and *Salmonella enteritidis* infections.<sup>10,11</sup> However, the associations were examined at the serotype and not phage type level, and as there are over 2500 *Salmonella* serotypes,<sup>3</sup> identification of a possible relationship with temperature at the level of phage type may inform refined

intervention strategies. As well as considering specific phage types, we focussed on the effect of heatwaves while these previous studies estimated the effect of temperature. Hence, public health implications for incidence of foodborne disease and prevention may vary depending on the mechanisms of these relationships on transmission of *Salmonella* infection.

*S. typhimurium* PT135 is a commonly reported phage type isolated from human infection, with *S. typhimurium* PT108 becoming more frequent.<sup>31</sup> The serotypes examined in this study are consistent with reports from other states in Australia<sup>31</sup> and have been isolated from chickens and eggs with consumption of both implicated in several outbreaks.<sup>32–36</sup> Despite the exclusion of foodborne outbreaks in our study, the five serotypes considered in our analyses are linked to animal and food sources, suggesting

heatwaves may play an important role in transmission of *Salmonella* infection through food contamination. Sustained elevation in temperature may affect transmission of *Salmonella* infection directly by multiplication of bacteria in the environment and in food. Indirect transmission may occur by a change in people's eating behaviours and food preferences (eating out, BBQ cooking) as well as food processing practices (poor food storage) during hotter days.<sup>6,10,15</sup>

The immediate effect of heatwave intensity was associated with an increased risk of *Salmonella* cases. We detected delayed effects, between four and six days for *S. typhimurium* PT9. For *S. typhimurium* PT108, there was evidence of delayed effects from days three through six. We also found the effects of heatwave intensity on *Salmonella* and *S. typhimurium* PT9 cases at day-14 lag indicating persisting effects at higher temperatures. Lag effects importantly indicate where and when food contamination could have occurred. Short lag times points to food contamination closer to the time of consumption, whereas longer time lags could indicate effects at the production processing stages.<sup>11,37</sup> Our results of lags with the greatest effect at zero, six and 14 days suggest that heatwaves may have an effect at the time of food preparation and consumption and at the time of food production and processing. A lag of up to 14 days is consistent with other studies in South Australia that examined the effects of warmer temperature on *Salmonella* cases.<sup>13,16</sup> In keeping with our findings, studies in other countries have detected lags of 1 week,<sup>10</sup> 2 weeks,<sup>14</sup> 1 month<sup>6,8,9,15</sup> and up to 2 months.<sup>7,12,17</sup> Notwithstanding this, consideration should be given to the short incubation period (between 8 and 72 h) for *Salmonella* as lag effects of temperature could be associated with varying incubation periods.<sup>3</sup>

Our study has several limitations. *Salmonella* infection is underreported given its reliance on a passive disease surveillance notification system.<sup>38</sup> However, it is unlikely that underreporting will affect estimates of the association between heatwaves and increased risk of salmonellosis. In addition, underreporting has remained relatively stable over the study period.<sup>16</sup> We were unable to exclude cases that travelled prior to onset of illness because the data were not fully captured in the disease notification surveillance system. Only a small proportion of cases are expected to travel and inclusion of cases that travelled is unlikely to affect the results.<sup>10</sup> As no studies have investigated the effects of heatwaves on salmonellosis notifications we applied the methods and analyses used by other studies that examined the relationship between heatwaves and mortality or morbidity.<sup>39–41</sup> As in these studies, we fitted a Poisson regression model using GEE based on the three studies cited above since this approach is commonly used to model clustered data and allows for autocorrelation to be taken into account. We did not adjust our reporting of statistical analyses for multiple comparisons<sup>42</sup> because of the exploratory nature of our study.

Given that the serotypes and phage types in our analyses were sensitive to the effects of heatwaves and are linked to animal and food sources, predominately chicken and eggs,<sup>32,34,43–45</sup> we postulate that heatwaves may play a role in transmission of infection through food contamination. Our results show that overall salmonellosis and

*S. typhimurium* PT135 cases increase over 39 °C in heatwaves – the optimum temperature for bacterial growth and multiplication. Ideal temperatures could enable the different *S. typhimurium* phage types to proliferate and develop quickly increasing risk of food contamination and subsequent risk of human infection.<sup>3</sup> Bacterial contamination of poultry meat, and livestock carcasses at the time of leaving abattoirs has been found to be higher in summer.<sup>46</sup> Additionally, lack of hand washing and improper storage during food handling and preparation in both domestic and retail settings can increase risk of food contamination.<sup>26</sup>

In this instance increased risk of *Salmonella* infection is generally preventable with correct food handling, preparation, storage and effective hygiene practices. Food and personal hygiene practices in domestic, retail and food catering settings promoted prior to the start of a heatwave will help to reduce the burden of *Salmonella* infection. It is essential for regulatory measures within retail and food catering industries to be in place when temperature increases to avoid food spoilage and contamination. Likewise, monitoring and enforcement of industry standards is also important.<sup>47</sup>

These public health interventions are particularly relevant given that populations worldwide are exposed to variability in weather patterns with increasingly common extreme events, such as heatwaves. Heatwaves are predicted to increase in frequency, intensity and duration, with consequential increases in mortality and morbidity arising from the effects of heatwaves. Furthermore, consideration and research should be given to exploring biological plausibility and epidemiological characteristics of *Salmonella* serotypes to better understand the association between heatwaves and salmonellosis, including replication in other areas of Australia and internationally. These findings support the need for targeted public health interventions and will inform development of policy recommendations for food-safety regulations and health-behaviour interventions that will mitigate the consequences of food-borne illness on human health.

## Competing interests

The authors declare that they have no competing interests.

## Acknowledgements

The authors thank staff from the Disease Surveillance and Investigation Section, Communicable Disease Control Branch, Department for Health and Ageing (SA Health) for their support in conducting this study.

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# **Chapter 7 Study 4: The effects of ambient temperature and heatwaves on daily *Campylobacter* cases in Adelaide, Australia, 1990 – 2012**

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## **7.1 Preface**

This chapter contains the final of a series of four articles contributing to this thesis. This article has been published in *Epidemiology and Infection*, and examines whether *Campylobacter* are affected by temperature in the warm season and during heatwaves. Previous studies concerning the relationship between temperature and *Campylobacter* cases have shown differences in the direction and association, either positive or negative. Many of these studies did not focus on warmer temperatures, and there were no studies that examined the effects of heatwaves on notifications. Hence, the purpose of this study was to examine the role of environmental factors, specifically temperature and increased risk of *Campylobacter* cases. The results from this thesis show that there is little evidence of an increase in risk of *Campylobacter* cases associated with temperature or heatwaves in the warm seasons. This is in keeping with studies conducted in a multi-city site in Europe, the UK, Adelaide and NZ. However, with rising ambient temperature and hotter weather, further exploration of the role of environmental factors is warranted, including increasing the evidence of reservoirs and transmission routes for *Campylobacter* infection.

## 7.2 Publication

Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effects of ambient temperature and heatwaves on daily *Campylobacter* cases in Adelaide, Australia, 1990 – 2012. *Epidemiology and Infection*. 2017;145(12):2603-2610. .

### Statement of Authorship

Title of Paper	The effects of ambient temperature and heatwaves on daily <i>Campylobacter</i> cases in Adelaide, Australia, 1990 – 2012
Publication Status	<input checked="" type="checkbox"/> Published <input type="checkbox"/> Accepted for Publication <input type="checkbox"/> Submitted for Publication <input type="checkbox"/> Unpublished and Unsubmitted work written in manuscript style
Publication Details	Milazzo A, Giles LC, Zhang Y, Koehler AP, Hiller J, Bi P. The effects of ambient temperature and heatwaves on daily <i>Campylobacter</i> cases in Adelaide, Australia, 1990 – 2012. <i>Epidemiology and Infection</i> . 2017; 145(12):2603-2610.

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Name of Principal Author (Candidate)	Adriana Milazzo		
Contribution to the Paper	Designed the study, contributed to the statistical framework, performed the analyses, interpreted the data, and drafted the manuscript		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

- i. the candidate's stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Signature		Date	20/11/2017

Milazzo, A., Giles, L.C., Zhang, Y., and Koehler, A.P., Hiller, J.E. and Bi, P. (2017). The effects of ambient temperature and heatwaves on daily *Campylobacter* cases in Adelaide, Australia, 1990–2012. *Epidemiology & Infection*, 145(12), 2603-2610.

NOTE: This publication is included in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

<https://doi.org/10.1017/S095026881700139X>

## Chapter 8 Discussion and recommendations

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This thesis has investigated the impact of ambient temperature on foodborne disease with two primary aims: 1) to explore knowledge, preferences and practices of food safety and food consumption patterns of *Salmonella* and *Campylobacter* cases, and their risk perception of foodborne illness in the warm weather, and 2) to examine the effects of warm season temperature and heatwaves on overall *Salmonella*, including serotypes and phage types, and *Campylobacter* notifications. Overall, the aim of the research was to provide evidence for public health policy and to contribute information towards the development of practical guidelines for foodborne disease prevention and control in the context of climate change.

No studies published to date have investigated the influence of warm season temperature and heatwaves on people's behaviour in relation to food hygiene and safety, and whether preferences for shopping, eating out and eating high-risk foods associated with foodborne disease increases their risk of illness. Little is also known about people's perception of whether high temperatures increases the risk of infectious gastrointestinal illness, and what people's preferences are for receiving food safety information in the warm season. While there is available evidence on the effects of temperature on *Salmonella* and *Campylobacter* cases, there are few studies concerning the effects of warm temperature, and none on heatwaves. Additionally, there are limited studies that investigate whether different *Salmonella* strains are affected differentially by temperature [52, 91, 92]. Multiple transmission pathways for *Salmonella* spp. that may be associated with other environmental factors [29, 150]. The current investigation is timely, given predicted rising temperatures and increasing frequency of heatwave events because of climate change. This presents a growing challenge for foodborne disease control and prevention. In this final chapter, key findings are presented, the limitations of the thesis are discussed, and



policy and public health practice recommendations and further research opportunities are highlighted.

## **8.1 Key findings and contributions**

### **8.1.1 Food safety practices, knowledge and preferences in warm weather**

The first aim (study 1) was to investigate food safety practices in the warm weather, assess the knowledge of people diagnosed with *Salmonella* or *Campylobacter* infection, and to determine whether these varied by socioeconomic status (income, level of education and socioeconomic disadvantage). A review of the literature identified no published studies (either population-based or on people diagnosed with foodborne disease) regarding people's knowledge, behaviour and preferences about foodborne disease related to heat. However, a number of studies, both internationally [44-46] and in Australia [26, 43], have investigated practices and knowledge related to food safety in the general population. Despite differences in populations (population-based and *Salmonella* and *Campylobacter* cases), results from the survey in this thesis are in keeping with those published studies described above.

Chapter 4 presents results from a questionnaire survey conducted among *Salmonella* and *Campylobacter* cases with a notified onset of illness in the warm season months. The relationship between socioeconomic status and food safety knowledge and practices, food preferences and knowledge about food safety information in the warmer weather was examined. Firstly, this study found that, overall, participants engaged in unsafe personal and food hygiene practices and unsafe practices related to food preparation. Unsafe practices included inadequate handwashing, not using separate cutting boards for raw meat and other food, and incorrect washing of cutting boards. As well as unsafe food practices, respondents also had poor knowledge of high-risk foods for *Salmonella* and *Campylobacter* infection, and of the correct refrigerator temperature setting, potentially leading to foodborne illness in the home.

Risky food behaviour and practices in the warm weather included leaving frozen meat out at room temperature to defrost. Other risk factors associated with behaviour and practices in the warmer weather were that respondents were more likely to have a barbeque, and those in the disadvantaged and aged over 60 years groups were more likely to consume high-risk foods for *Salmonella* and *Campylobacter* infection such as chicken and eggs. Preferences for information receipt about food safety in warm weather varied, with females more likely than males to prefer television for receiving information, while those most disadvantaged were less likely to prefer the internet and printed material. These results indicate that it is important to identify community members' preferences for receipt of food safety information, so that appropriate health education approaches can be developed accordingly.

### **8.1.2 Relationship between ambient temperature and heatwaves and *Salmonella* and serotype notifications**

The second and third aims (studies 2 and 3) of this thesis were to quantify the relationship between temperature in the warm seasons and during heatwaves and daily *Salmonella* counts and to assess if the effects on risk of infection varied among the five most commonly notified serotypes/phage types in Adelaide. Information is available about the effects of temperature on *Salmonella* notifications in countries such as Europe, the UK, the USA, Canada, NZ and Australia. However, a review of the literature revealed little information regarding associations between temperature in the warm seasons and no studies on the effect of heatwaves on *Salmonella* counts. There is also little information on the effects of temperature on *Salmonella* serotypes with none on phage types. It was considered essential to collect evidence to show that there may be greater sensitivity to increased ambient temperature and foodborne diseases among different *Salmonella* serotypes and phage types as some may be more likely to be endemic in the environment, thus subject to climate variability.

In Chapter 5, we demonstrated that an increased risk in *Salmonella* counts was associated with the warm seasons and that for certain *S.Typhimuirum* phage types, risk increased at much higher temperatures. We observed increased cases of *S.Typhimurium* phage type (PT) 9 and *S.Typhimurium* PT108 notifications above a temperature threshold of 39°C. The results also revealed that the effects of temperature on overall *Salmonella* notifications and certain *Salmonella* serotypes and *S.Typhimurium* phage types were generally lagged by up to 14 days, in keeping with findings from a previous study conducted in Adelaide [97]. These lag times suggest that temperature could have an influence on the primary food production stages which has implications for public health interventions and food safety regulation. At the primary production stage contamination may occur through the use of manure and water to fertilise and irrigate fresh fruit and vegetables [69]. Because *Salmonella* spp. can survive outside of animal or human hosts, higher ambient temperatures may enhance replication in manure. This may facilitate transmission between animals, particularly in conditions associated with intensive farming and overcrowding [23]. Given the inter-relationship between the environment and animal and human health, One Health as an approach for infectious disease control and prevention should be considered. One Health aims to integrate human, animal and environmental health, with consideration given to the role of the changing environment, such as climate change, and the effect this has on existing and emerging infectious diseases [151].

It is even more important in the event of hotter weather to safeguard against poor temperature control during processing and manufacturing, and to ensure optimum hygiene levels [152]. Consequently, identifying temperature thresholds, as we have done in study 2, has important public health implications for foodborne disease control and prevention. Temperature thresholds can be useful in providing evidence for the development of early heat warning systems and alerts. Effective measures to reduce the risk of foodborne

disease can be implemented at any stage along the food chain - from primary production, processing, transportation, retail/trading and kitchen, and finally to human consumption.

The results presented in Chapter 6 showed clear evidence that the effect of heatwaves on *Salmonella* infection was associated with a significant increase in daily notifications, which was also the case for *S.Typhimurium* PT135. Higher temperatures during heatwaves had a significant effect on daily counts of overall salmonellosis with a larger increase in risk of infection compared to the effect of temperature in the warmer season. Similar to our findings on the effects of temperature on salmonellosis in the warm seasons, we also found a lagged effect of temperature on cases of up to 14 days during heatwaves. Detecting lagged effects as we have done in this thesis is an important issue for foodborne disease prevention and control. Lag effects provide an indication where food contamination could have occurred. Short lag times with temperature points to food contamination closer to the time of consumption, whereas longer time lags could indicate effects at the production processing stages.

### **8.1.3 Relationship between ambient temperature and heatwaves on *Campylobacter* notifications**

The aim of study 4 was to assess the effect of temperature and heatwaves in the warm seasons on the incidence of daily *Campylobacter* notifications in Adelaide. While studies, mainly emanating from the UK, USA, Canada and Denmark, have demonstrated a positive association with temperature, other studies in Australia, NZ and a multi-site international study (mainly Europe and Australasia) concluded no effect of temperature on *Campylobacter* counts (Table 2 and 3, Chapter 2). However, these studies did not relate temperature to warm seasons with positive effects associated with an increase in cases occurring at lower temperatures. Further to this, no studies have investigated the effects of heatwaves on *Campylobacter* notifications.

Inconsistent findings regarding the relationship between temperature and *Campylobacter* notifications, and the paucity of information concerning heatwaves and *Campylobacter* notifications led to this study. Chapter 7 confirms the results from the studies conducted in Adelaide [99], NZ [94] and several European countries included in the multi-site study [107] that temperature does not increase the risk of *Campylobacter* infection. With these findings, it was not surprising to find that the effect of heatwaves on daily *Campylobacter* notifications reported in Adelaide was also not significant. Our results highlight that temperature does not have an effect on the incidence of *Campylobacter* cases in a temperate climate, yet in other regions and countries a significant effect exists. This suggests that the impact of temperature on cases varies within and between geographical regions, with environmental factors influencing the effects of temperature thereby affecting disease transmission routes.

## **8.2 Significance of this thesis**

Foodborne disease is an important public health issue that places a significant burden on the morbidity of populations, with social and economic impacts. Epidemiological studies have confirmed that increasing temperature may result in excess cases of gastrointestinal disease in the population. However, research on the impact of warm season temperature and heatwaves has received very little attention. To our knowledge, this is the first research conducted anywhere to assess the effects of ambient temperature in the warm seasons and during heatwaves on overall *Salmonella* notifications including serotypes and phage types, and on *Campylobacter* notifications. This is important given that *Salmonella* and *Campylobacter* are the two most commonly reported causes of infectious gastrointestinal diseases in the world [10]. Our study is also the first to have explored whether human behaviour and practices related to food safety are influenced by warm season temperature.

This research is significant because we have identified that temperature, more importantly extreme heat, has a significant effect on the incidence of *Salmonella* notifications.

Quantitative estimates of the number of expected cases attributed to temperature enables a better understanding of the risks associated with temperature in the warm seasons and heatwaves, supporting the development of policy and foodborne disease prevention strategies. This insight is particularly useful in assessing the risk among different *Salmonella* serotypes and phage types which we found were associated with heat, and are also commonly linked to foodborne disease outbreaks. This contributes to the understanding of possible source specific strains that could be related to seasons and climate. Conversely, no effect on *Campylobacter* counts was detected; nevertheless this raises issues about climate sensitive variations, and regional differences which may not be accurately represented in ecological studies. Future climate change projections linked to higher temperatures gives foodborne disease the potential to become an even more significant public health problem.

Another highlight of our research contributing to the overall significance of this thesis was the survey of people diagnosed with *Salmonella* or *Campylobacter* infection, the first of its kind, to investigate food safety practices, preferences and perceptions of risk related to foodborne disease. The results will provide information for the development of food safety awareness in hot weather for domestic households, as well as for commercial food retailers.

This thesis has made a significant contribution to the knowledge of the relationship between temperature and foodborne disease. Overall the results from studies 1 through 4 in this thesis have wide applicability for heat-related foodborne disease prevention in the policy arena, including practical public health interventions at a local level with international adaptability.

### **8.3 Limitations**

The limitations of each study have been discussed in the relevant chapters, and will not be repeated here, rather in this section the major limitations of the study overall will be discussed. A limitation of study 1 (Chapter 4) was that survey participants were restricted to people diagnosed with *Campylobacter* and/or *Salmonella* infection. Whilst it would have been ideal to have had a comparison group so we could ascertain whether behaviour patterns differed from those with and without infection, it was not possible to conduct a population-wide study given the duration of the PhD study and feasibility and cost of organising such a large survey. However, as discussed in Section 8.1.1, our findings on food hygiene and practices are generally in line with previous surveys on food safety at a population-level. Although we did not find a significant relationship between food safety practices and food preferences related to warm weather, recall bias may have been an issue as some respondents would have answered on days of extreme heat, whereas other respondents would have completed the survey on less extreme heat days.

In ecological studies, such as those presented in Chapters 5, 6 and 7, the unit of observation and analysis is at the population-level rather than individual. This study design is prone to bias, whereby assessments observed on a population-level are used to assume associations at the individual-level [81, 153]. Due to ethical concerns, it was not feasible to obtain exposure data from each individual notified case. Therefore, the ecological study design is useful in ascertaining short-term associations between exposure and outcome in large populations over time [79, 81].

Heatwave and human health studies face a range of methodological challenges. There is no standard or universally accepted definition of what constitutes a heatwave because the impact of heatwaves on human health is influenced by many factors including local acclimatisation, local climatic characteristics, social and cultural context, vulnerability and adaptation [119, 154, 155]. In this thesis, a heatwave definition used in previous heat-

health studies conducted in Adelaide was applied [5]. Intensity, duration and timing in season were the facets of heatwaves considered in this thesis. Our results support the findings from a Brisbane study which compared emergency hospital admissions and mortality data using different heatwave definitions [119]. Those findings indicate that commonly used definitions are not appropriate for Brisbane and the results did not lead to a working heatwave definition for use [119].

Application of temperature thresholds and metrics varies in climate change and population health outcomes research. Most studies use daily maximum and minimum temperatures to define heatwaves or extreme heat [156], but in this thesis maximum temperature was used. Data concerning maximum temperature were obtained from a weather station in Adelaide (Kent Town) representing the heat exposure for all residents in the metropolitan region. Heat exposure may vary within regions and as there are several weather monitoring stations in Adelaide itself, this was not accounted for in the analysis leading to potential misrepresentation of temperature differences. However, recordings from Kent Town station, according to BOM, are representative of weather conditions across the metropolitan region of Adelaide as there is little variation in temperature, and so misclassification of exposure is unlikely to be of consequence to our findings.

The counts for *Salmonella* serotypes are sparse given that there are an additional 178 serotypes or phage types that contribute to the overall counts, hence the results in this thesis should be interpreted with caution for some of the phage types with low counts. Most of the previous studies have explored the association between temperature and *Salmonella* transmission, with this study extending the previous research in this area and identifying which specific serotype(s) have been affected by the high temperatures. Therefore, in this thesis the phage types were examined separately despite small numbers.



Despite these limitations, the strength of this research is the multi-faceted approach taken by not only quantifying the relationship between temperature and heatwaves on *Salmonella* and *Campylobacter* incidence, but an attempt to be cognisant of the behaviour and knowledge of people, which could be determined by socioeconomic status, that may influence their practices in the warm weather.

## **8.4 Recommendations**

This thesis has provided an overview of the relationship between warm weather temperature and heatwaves on the incidence of specific foodborne diseases. The implications of the findings from this thesis revolve around two specific themes for future research and direction related to foodborne disease prevention: public health policy and practice, and methodological approaches for climate change and foodborne disease.

### **8.4.1 Public health policy and practice**

The delayed effect of temperature on foodborne disease is important as it can indicate the timing at which the food chain contamination has occurred. Interventions should focus on public health policy related to food safety programs with manufacturers, processing plants and commercial retailers playing an important role in preventing the risk of foodborne disease. At a policy level, relevant health and industry sectors should take an active role in developing food regulation and practice guidelines for preventing and reducing the risk of foodborne disease, with additional attention given to that associated with warm season temperature and heatwaves. Further, inter-sectoral action is required to reduce climate change impacts overall, which can be achieved through concerted efforts to work towards adaptation and mitigation measures.

Employers in the food sector need to provide information and training for their staff at all tiers of the organisation - from producers, and transporters to food handlers, on food hygiene in the warm weather and during heatwaves. It is essential for regulatory measures

within retail and food catering industries to be in place when temperature increases in order to avoid food spoilage and contamination. Adequate hygiene and food safety practices in animal husbandry, food handlers and food storage and sales can be impacted by warm weather and more so with extreme temperatures as observed in our study, whereby the risk of *Salmonella* infection increased above the 95<sup>th</sup> percentile, adding further evidence to the importance of detecting temperature thresholds for disease control and prevention.

In this thesis, lags of up to 14 days were found for both *Salmonella* and *Campylobacter* infection, suggesting that consumers need to be made aware of the implications for food safety, particularly related to food preparation, handling and storage at the time of consumption. Community level education, health promotion and awareness raising are critical and could be incorporated as part of an early warning system at the start of heatwave events. With this in mind, a high standard of hygiene procedures and practices in food handling, conservation and cooking are important all year around with an emphasis on the warm seasons as this is when bacterial loads in primary production could be potentially high. Consumers should be aware of how to prevent and reduce the risk of foodborne disease when ambient temperatures are high or during a heatwave event by use of appropriate food storage temperatures. As discussed in Section 8.1.2, temperature thresholds can be useful in providing evidence for the development of early heat warning systems. Raising awareness about risks of foodborne disease and the ability to predict these risks accounting for temperature thresholds should be introduced in the workplace (primary production, processing, transportation, commercial retailers), as well as alerting the community about the need for safe food practices in households in hotter weather.

Health promotion strategies and specific information for the development of practice guidelines for community-level education and awareness will play an important role in foodborne prevention in the summer season. These strategies and avenues for communication must be selected according to the target groups; the findings in this thesis

demonstrated differences in preferences for receiving information about heat and foodborne prevention by socioeconomic disadvantage, gender and age group. In addition to this, there is a need for further research on the type of tailored health intervention messages to be disseminated to those groups at risk and also to the general public, and an evaluation of the effectiveness of such messages.

#### **8.4.2 Future directions**

Future directions for research focussing on people's food safety practices include extending the work of study 1 to include a population-based survey conducted in real-time in order to capture the weather event at the time, for example during heatwaves. This would have the benefit of minimising potential recall bias so respondents can accurately recall the practices that they in fact take in the warmer months. On the other hand, respondents could be presented with different temperature scenarios at the start of the survey and asked to respond accordingly based on what they would do at the time of a particular temperature forecast and comparing it to their usual practice.

Exploration of the association between warm temperature, heatwaves and *Salmonella* serotypes in different climatic regions should be further researched to identify different transmission pathways for various strains and if they are influenced by weather.

Temperature, duration and the impact of heatwaves vary between geographical regions, and so definitions should be constructed accounting for location, including other relevant climatic conditions such as relative humidity, as well as the behavioural and physiological adaptability of the population [153]. Adding to this is the need for further research into the role of the environment and climatic variables with the emerging evidence of climate change and increasing warmer weather because of the disparate results across studies of the effect of temperature and the increased risk of *Campylobacter* infection.

To further understand geographical variations on the impact of heatwaves, a relatively novel index, the excess heat factor (EHF) may be used to measure the intensity of heatwaves on health outcomes, applied to different locations [157]. The application of the EHF index relative to local climates warrants further research as it may be useful in determining heatwave severity and people's adaptation, relative to risk of foodborne disease at the local climate level.

Implementing an integrated surveillance system to monitor human and animal health and the environment, such as the One Health approach is an important public health measure which may lead to effective warning systems, and rapid responses in detecting infectious disease outbreaks as impacted by the role of the changing environment, including climate change.

Ecological studies can be effective in finding associations between exposure and health outcomes, which may warrant further investigation [128]. There are a number of factors that were not within the scope of this research that could be further explored; use of multiple data sources to investigate the complex nature of climate change and infectious diseases; patterns of changing incidence within each summer; analysis of different influencing factors, for example socioeconomic status, demographic characteristics, and information on households, and whether a home is air-conditioned, as this may impact some of the risk factors for foodborne disease in conjunction with heatwaves.

Foodborne disease is an important public health issue that places a significant economic burden on populations including loss of productivity due to the number of work days lost to illness. Further analyses on the impact of climate change related to warmer temperature and heatwaves on productivity and health economics should be considered in an effort to estimate the cost-benefit associated with economic loss and interventions.

## **8.5 Concluding remarks**

The findings from this study will contribute further knowledge about the burden of foodborne disease associated with warmer ambient temperature and heatwaves. Our study is the first to have explored whether human behaviour and practices related to food safety change during warm season months. This is important given that warmer ambient temperatures are projected to rise, both globally and in Australia, if climate change continues, and is projected to have a substantial effect on the global burden of foodborne disease.

The evidence from this thesis confirms the effect of warm temperature and heatwaves on excess *Salmonella* notifications and that there is greater sensitivity among different *Salmonella* strains. Opposed to this finding is that temperature has a limited role in increased incidence of *Campylobacter* notifications in the warm season, and there is no effect of heatwaves on cases. Our research has not found an explanation for the lack of effect of warmer temperature on *Campylobacter* infections. Nevertheless, the results from this thesis contribute not only to the knowledge gap in areas highlighted earlier, but also to public health practices in disease control and prevention.

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## Appendix A: Food safety invitation letter, information sheet and consent form

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- Invitation letter sent to adults diagnosed with *Campylobacter*
- Invitation letter sent to parents/guardians of children diagnosed with *Campylobacter*
- Invitation letter sent to adults diagnosed with *Salmonella*
- Invitation letter sent to parents/guardians of children diagnosed with *Salmonella*
- Information sheet and consent form for adults diagnosed with *Campylobacter*
- Information sheet and consent form for parents/guardians and children diagnosed with *Campylobacter*
- Information sheet and consent form for adults diagnosed with *Salmonella*
- Information sheet and consent form for parents/guardians and children diagnosed with *Salmonella*



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ABN 97 643 356 590  
cdc@health.sa.gov.au  
[www.health.sa.gov.au/pehs](http://www.health.sa.gov.au/pehs)

March 2013

Dear Sir/Madam

**Re: Participation in a project about food safety on hot days**

You are invited to participate in a project about people's perceptions and practices in relation to food preferences and food preparation in hot weather. This study will contribute further knowledge about gastroenteritis such as *Campylobacter* infection and its association with hot weather, thus providing recommendations for prevention.

This study is a joint project with the Communicable Disease Control Branch (CDCB) SA Health and The University of Adelaide. You received this invitation letter because you were recently notified to CDCB, SA Health with *Campylobacter* infection. Only CDCB has your personal contact details which are kept confidential and identifying information will not be disclosed for any other purpose without your consent. Researchers at The University of Adelaide do not have any of your contact details and if you agree to participate in the survey you will not be asked to divulge your name or information that could potentially identify who you are.

Participation in this project is voluntary. If you agree to participate, the survey will take about 15 minutes to complete. You will find attached a copy of the questionnaire, an Information Sheet about the study and a Consent Form.

Completion of the survey is through any of the 3 options listed below:

**1. Web based**

Please click on the following link to find the survey

[https://www.surveymonkey.com/s/campyl\\_hot](https://www.surveymonkey.com/s/campyl_hot)

**2. Hard copy**

A copy of the questionnaire is attached. Use the enclosed reply paid envelope to return the completed questionnaire.

**3. By telephone**

You may ring the researcher at The University of Adelaide and complete the survey over the telephone. Contact Adriana Milazzo ph) 8313 0199.

If you would like further information about this study before proceeding to participate in the survey please contact Ms Adriana Milazzo, Principal Researcher, The University of Adelaide, on 8313 0199 or by email [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au).

Yours sincerely

Director  
Communicable Disease Control Branch



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March 2013

Dear Parent/Guardian

**Re: Participation in a project about food safety on hot days**

ABN 97 643 356 590

[cdbc@health.sa.gov.au](mailto:cdbc@health.sa.gov.au)

[www.health.sa.gov.au/pehs](http://www.health.sa.gov.au/pehs)

You and your child are invited to participate in a project about people's perceptions and practices in relation to food preferences and food preparation in hot weather. This study will contribute further knowledge about gastroenteritis such as *Campylobacter* infection and its association with hot weather, thus providing recommendations for prevention.

This study is a joint project with the Communicable Disease Control Branch (CDCB) SA Health and The University of Adelaide. You received this invitation letter because your child was recently notified to CDCB, SA Health with *Campylobacter* infection. Only CDCB has your child's personal contact details which are kept confidential and identifying information will not be disclosed for any other purpose without your consent. Researchers at The University of Adelaide do not have any of your contact details and if you agree to participate in the survey you will not be asked to divulge you or your child's name or information that could potentially identify who you are.

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Yours sincerely

Director  
Communicable Disease Control Branch



Government of South Australia  
SA Health

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April 2013

Dear Sir/Madam

**Re: Participation in a project about food safety on hot days**

You are invited to participate in a project about people's perceptions and practices in relation to food preferences and food preparation in hot weather. This study will contribute further knowledge about gastroenteritis such as *Salmonella* infection and its association with hot weather, thus providing recommendations for prevention.

This study is a joint project with the Communicable Disease Control Branch (CDCB) SA Health and The University of Adelaide. You received this invitation letter because you were recently notified to CDCB, SA Health with *Salmonella* infection. Only CDCB has your personal contact details which are kept confidential and identifying information will not be disclosed for any other purpose without your consent. Researchers at The University of Adelaide do not have any of your contact details and if you agree to participate in the survey you will not be asked to divulge your name or information that could potentially identify who you are.

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**3. By telephone**

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If you would like further information about this study before proceeding to participate in the survey please contact Ms Adriana Milazzo, Principal Researcher, The University of Adelaide, on 8313 0199 or by email [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au).

Yours sincerely

Director  
Communicable Disease Control Branch



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March 2013

Dear Parent/Guardian

**Re: Participation in a project about food safety on hot days**

You and your child are invited to participate in a project about people's perceptions and practices in relation to food preferences and food preparation in hot weather. This study will contribute further knowledge about gastroenteritis such as *Salmonella* infection and its association with hot weather, thus providing recommendations for prevention.

This study is a joint project with the Communicable Disease Control Branch (CDCB) SA Health and The University of Adelaide. You received this invitation letter because your child was recently notified to CDCB, SA Health with *Salmonella* infection. Only CDCB has your child's personal contact details which are kept confidential and identifying information will not be disclosed for any other purpose without your consent. Researchers at The University of Adelaide do not have any of your contact details and if you agree to participate in the survey you will not be asked to divulge you or your child's name or information that could potentially identify who you are.

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Yours sincerely

Director  
Communicable Disease Control Branch



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## Information Sheet

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**To:** Potential participants

**Project title:** Food safety on hot days.

**Principal researcher**

Ms Adriana Milazzo (Discipline of Public Health, School of Population Health, The University of Adelaide).

**Research associates**

Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide).

Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

---

### 1. Your consent

This Information sheet contains detailed information about the study. Once you understand what the project is about and if you agree to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, and either returning the completed questionnaire or agreeing to consent by participating in the survey on-line, you indicate that you understand the information and that you give your consent for you to participate. The Information Sheet and Consent Form are for you to keep as a record.

### 2. Purpose and Background

The aim of this project is to explore if people's eating behaviours and food preferences, as well as food processing practices during hot days, may contribute to increased cases of infectious gastroenteritis, such as *Campylobacter*. You are invited to participate in this project because you were recently notified to the Communicable Disease Branch, SA Health with *Campylobacter* infection.

### 3. Procedure

If you agree to participate, you will be asked to complete a short 15 minute survey about your food preferences and food preparation in your household during hot weather. This will include questions about food storage, transportation of food from the supermarket/shop to home, type of food purchased during hot weather and eating out on hot days.

### 4. Possible Risks

There are no foreseeable risks of participating in this survey. However, if you do participate and find that you are uncomfortable or concerned about your responses to any of the survey questions, or if you find participation in the study distressing, you should contact Ms Adriana Milazzo on 08 8313 0199 as soon as convenient.

### 5. Privacy, Confidentiality and Disclosure of Information

You can be assured that you will not be identified by name in any way in the reporting of the study results in publications and conference presentations. Any information we collect from you that can identify you will remain confidential and will be stored in a locked cabinet within the Discipline of Public Health at The University of Adelaide for a minimum of 5 years from the date of publication. If you complete the survey electronically you can be assured that your responses will be transmitted over a secure, encrypted connection. Only Adriana Milazzo will have access to the data via a unique password to be able to log on and view the completed survey.

### 6. Results of Project

At the completion of the study a summary of the findings will be available for any interested participants. Please email [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au) if you would like to receive a copy of this report.

### 7. Participation is voluntary

Participation in the project is voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage until you have submitted your results to the researchers through completion of the questionnaire either on-line or hard copy, after which time your data are made anonymous and it will not be possible to remove your contributions from the analysis. Your decision whether to take part or not take part, will not affect your relationship with SA Health or The University of Adelaide in any way.

### 8. Ethical Guidelines

The study will be carried out in accordance with the National Statement on Ethical Conduct in Human research (2007). This statement has been developed to protect the interest of people who agree to participate in human research studies. The ethical aspects of this research project have been approved by the Human Research Ethics Committee of SA Health, project number HREC/12/SAH/93. The research will be carried out in the Discipline of Public Health, School of Population Health, The University of Adelaide, Level 7, 178 North Terrace, Adelaide.

**9. Complaints**

Should you have any concerns about the conduct of this research project, please contact the Executive Officer, Human Research Ethics Committee, Research and Ethics Policy Unit, SA Health, telephone 08 8226 6367, fax 08 8226 7088 or email [hrec@health.sa.gov.au](mailto:hrec@health.sa.gov.au)  
Please quote project number HREC/12/SAH/93.

<b>Consent Form</b>
---------------------

**Date:** February 2013

**Full project title:** Food safety on hot days

**Researchers:** Ms Adriana Milazzo, Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide) and Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health)

---

**Please read below and tick the relevant statement:**

- I have read and understood the attached Information Sheet
- I freely consent to participate in this study according to the conditions in the Information Sheet
- I have been given a copy of the Information Sheet and Consent Form to keep

The researchers have agreed not to reveal my identity and personal details, including where information about this study is published or presented in any public form.

**Participants signature** ..... **Date** .....

My contact details are: Ms Adriana Milazzo  
Discipline of Public Health  
Level 7, 178 North Terrace, Adelaide,  
School of Population Health  
The University of Adelaide 5000  
Ph) 8313 0199  
Email) [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au)

---

## Information Sheet for Parents/Guardians

---

**To:** Parents/guardians of children or young people

**Project title:** Food safety on hot days.

**Principal researcher**

Ms Adriana Milazzo (Discipline of Public Health, School of Population Health, The University of Adelaide).

**Research associates**

Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide).

Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

---

### 1. Your consent

This Information sheet contains detailed information about the study. Once you understand what the project is about and if you agree to take part in it with your child, you will be asked to sign the Consent Form. By signing the Consent Form, and either returning the completed questionnaire or agreeing to consent by participating in the survey on-line, you indicate that you understand the information and that you give your consent for you and your child to participate. The Information Sheet and Consent Form are for you to keep as a record.

### 2. Purpose and Background

The aim of this project is to explore if people's eating behaviours and food preferences, as well as food processing practices during hot days, may contribute to increased cases of infectious gastroenteritis, such as *Campylobacter*. You are invited to participate in this project because your child was recently notified to the Communicable Disease Branch, SA Health with *Campylobacter* infection.

### 3. Procedure

If you and your child agree to participate, you will be asked to complete a short 15 minute survey about your child's food preferences and food preparation in your household during hot weather. This will include questions about food storage, transportation of food from the supermarket/shop to home, type of food purchased during hot weather and eating out on hot days.

### 4. Possible Risks

There are no foreseeable risks of participating in this survey. However, if you do participate and find that you or your child are uncomfortable or concerned about your responses to any of the survey questions, or if you find participation in the study distressing, you should contact Ms Adriana Milazzo on 08 8313 0199 as soon as convenient.

### 5. Privacy, Confidentiality and Disclosure of Information

You can be assured that you and your child will not be identified by name in any way in the reporting of the study results in publications and conference presentations. Any information we collect from you that can identify your child will remain confidential and will be stored in a locked cabinet within the Discipline of Public Health at The University of Adelaide for a minimum of 5 years from the date of publication. If you complete the survey electronically you can be assured that your responses will be transmitted over a secure, encrypted connection. Only Adriana Milazzo will have access to the data via a unique password to be able to log on and view the completed survey.

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At the completion of the study a summary of the findings will be available for any interested participants. Please email [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au) if you would like to receive a copy of this report.

### 7. Participation is voluntary

Participation in the project is voluntary. If you do not wish to take part you are not obliged to. If you and your child decide to take part and later change your mind, you are free to withdraw from the study at any stage until you have submitted your results to the researchers through completion of the questionnaire either on-line or hard copy, after which time your data are made anonymous and it will not be possible to remove your contributions from the analysis. Your decision whether to take part or not take part, will not affect your relationship with SA Health or The University of Adelaide in any way.

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Please quote project number HREC/12/SAH/93.

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## Information for children and young people

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Hello! My name is Adriana Milazzo, I am a student at The University of Adelaide. I am doing a project to find out if what people like to eat, or where they do their shopping, and where they eat out is different on a hot day compared to a cold day.

When I finish my project it will be part of my degree, called a "PhD". I have some help with my project from teachers who work at the University, Dr Peng Bi and Dr Ying Zhang; they are called my supervisors and we work in the Discipline of Public Health. I have another supervisor, Dr Ann Koehler who works for the Health Department, called SA Health. She is in charge of the section where your doctor sent information about you when you were sick with diarrhoea (runny poos), or tummy pains or vomiting. This illness is called *Campylobacter* infection, and people at the Health Department try to find out if others got sick. They want to know if people ate the same food that could have caused them to get sick.

You were sent this letter from Dr Koehler at the Health Department who knows your information; she sent it on my behalf because I can't see your information. If you would like to take part, your parent or carer will help you to fill in the questions. Some questions will be about you and some will be about what happens in your house on a hot day, your parent will fill that bit out. You should talk to your parents about the project too.

Only my supervisor and I will see your answers, but please don't worry as I won't know that the answers came from you as we are not asking you to give your name or any information that could tell us who you are. You can fill in the questions on the internet, or ring me and we can do it over the phone, or you can fill in the questions on paper. After the project is over, I will lock all the results away safely in the Discipline of Public Health for 5 years. I have to do this because it is a University rule. After this time they will be destroyed.

Remember, you don't have to take part unless you want to. If you have any questions you should talk to your parent or carer. If they don't know the answer to your questions, they can contact me (see below for my details), or the Research Ethics Officer at the Health Department (SA Health).

If you want to be part of the project, and your parent also agrees, please sign your name (if you can write) on the Consent Form where it says "Child or young person signature", and also get your Parent/Guardian to sign it as well.

My contact details are: Ms Adriana Milazzo  
Discipline of Public Health  
Level 7, 178 North Terrace, Adelaide,  
School of Population Health  
The University of Adelaide 5000  
Ph) 8313 0199  
Email) [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au)

**Consent Form  
Parents/Guardians and Children/Young People**

**Date:** February 2013

**Full project title:** Food safety on hot days.

**Researchers:** Ms Adriana Milazzo, Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide) and Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

---

**Please read below and tick the relevant statement if participating on behalf of your child:**

- I have read and understood the attached Information sheets (a copy for Children and a copy for Parents/Guardians)
- I freely consent to participate in this study according to the conditions in the Information Sheet
- I give permission for my child to participate in this study according to the conditions in the Information Sheet
- I have been given a copy of the Information and Consent Form to keep

The researchers have agreed not to reveal my identity and personal details, including where information about this study is published or presented in any public form.

**Parent/Guardian signature**..... **Date**.....

**Child or young person's signature**..... **Date**.....  
(if able to)

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## Information Sheet

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**To:** Potential participants

**Project title:** Food safety on hot days.

**Principal researcher**

Ms Adriana Milazzo (Discipline of Public Health, School of Population Health, The University of Adelaide).

**Research associates**

Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide).

Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

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### 1. Your consent

This Information sheet contains detailed information about the study. Once you understand what the project is about and if you agree to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, and either returning the completed questionnaire or agreeing to consent by participating in the survey on-line, you indicate that you understand the information and that you give your consent for you to participate. The Information Sheet and Consent Form are for you to keep as a record.

### 2. Purpose and Background

The aim of this project is to explore if people's eating behaviours and food preferences, as well as food processing practices during hot days, may contribute to increased cases of infectious gastroenteritis, such as *Salmonella*. You are invited to participate in this project because you were recently notified to the Communicable Disease Branch, SA Health with *Salmonella* infection.

### 3. Procedure

If you agree to participate, you will be asked to complete a short 15 minute survey about your food preferences and food preparation in your household during hot weather. This will include questions about food storage, transportation of food from the supermarket/shop to home, type of food purchased during hot weather and eating out on hot days.

### 4. Possible Risks

There are no foreseeable risks of participating in this survey. However, if you do participate and find that you are uncomfortable or concerned about your responses to any of the survey questions, or if you find participation in the study distressing, you should contact Ms Adriana Milazzo on 08 8313 0199 as soon as convenient.

### 5. Privacy, Confidentiality and Disclosure of Information

You can be assured that you will not be identified by name in any way in the reporting of the study results in publications and conference presentations. Any information we collect from you that can identify you will remain confidential and will be stored in a locked cabinet within the Discipline of Public Health at The University of Adelaide for a minimum of 5 years from the date of publication. If you complete the survey electronically you can be assured that your responses will be transmitted over a secure, encrypted connection. Only Adriana Milazzo will have access to the data via a unique password to be able to log on and view the completed survey.

### 6. Results of Project

At the completion of the study a summary of the findings will be available for any interested participants. Please email [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au) if you would like to receive a copy of this report.

### 7. Participation is voluntary

Participation in the project is voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage until you have submitted your results to the researchers through completion of the questionnaire either on-line or hard copy, after which time your data are made anonymous and it will not be possible to remove your contributions from the analysis. Your decision whether to take part or not take part, will not affect your relationship with SA Health or The University of Adelaide in any way.

### 8. Ethical Guidelines

The study will be carried out in accordance with the National Statement on Ethical Conduct in Human research (2007). This statement has been developed to protect the interest of people who agree to participate in human research studies. The ethical aspects of this research project have been approved by the Human Research Ethics Committee of SA Health, project number HREC/12/SAH/93. The research will be carried out in the Discipline of Public Health, School of Population Health, The University of Adelaide, Level 7, 178 North Terrace, Adelaide.

**9. Complaints**

Should you have any concerns about the conduct of this research project, please contact the Executive Officer, Human Research Ethics Committee, Research and Ethics Policy Unit, SA Health, telephone 08 8226 6367, fax 08 8226 7088 or email [hrec@health.sa.gov.au](mailto:hrec@health.sa.gov.au)

Please quote project number HREC/12/SAH/93.

<b>Consent Form</b>
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**Date:** January 2013

**Full project title:** Food safety on hot days

**Researchers:** Ms Adriana Milazzo, Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide) and Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health)

---

**Please read below and tick the relevant statement:**

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**Participants signature** ..... **Date** .....

My contact details are: Ms Adriana Milazzo  
Discipline of Public Health  
Level 7, 178 North Terrace, Adelaide,  
School of Population Health  
The University of Adelaide 5000  
Ph) 8313 0199  
Email) [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au)

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## Information Sheet for Parents/Guardians

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**To:** Parents/guardians of children or young people

**Project title:** Food safety on hot days.

**Principal researcher**

Ms Adriana Milazzo (Discipline of Public Health, School of Population Health, The University of Adelaide).

**Research associates**

Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide).

Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

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### 1. Your consent

This Information sheet contains detailed information about the study. Once you understand what the project is about and if you agree to take part in it with your child, you will be asked to sign the Consent Form. By signing the Consent Form, and either returning the completed questionnaire or agreeing to consent by participating in the survey on-line, you indicate that you understand the information and that you give your consent for you and your child to participate. The Information Sheet and Consent Form are for you to keep as a record.

### 2. Purpose and Background

The aim of this project is to explore if people's eating behaviours and food preferences, as well as food processing practices during hot days, may contribute to increased cases of infectious gastroenteritis, such as *Salmonella*. You are invited to participate in this project because your child was recently notified to the Communicable Disease Branch, SA Health with *Salmonella* infection.

### 3. Procedure

If you and your child agree to participate, you will be asked to complete a short 15 minute survey about your child's food preferences and food preparation in your household during hot weather. This will include questions about food storage, transportation of food from the supermarket/shop to home, type of food purchased during hot weather and eating out on hot days.

### 4. Possible Risks

There are no foreseeable risks of participating in this survey. However, if you do participate and find that you or your child are uncomfortable or concerned about your responses to any of the survey questions, or if you find participation in the study distressing, you should contact Ms Adriana Milazzo on 08 8313 0199 as soon as convenient.

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Please quote project number HREC/12/SAH/93.

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## Information for children and young people

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Hello! My name is Adriana Milazzo, I am a student at The University of Adelaide. I am doing a project to find out if what people like to eat, or where they do their shopping, and where they eat out is different on a hot day compared to a cold day.

When I finish my project it will be part of my degree, called a "PhD". I have some help with my project from teachers who work at the University, Dr Peng Bi and Dr Ying Zhang; they are called my supervisors and we work in the Discipline of Public Health. I have another supervisor, Dr Ann Koehler who works for the Health Department, called SA Health. She is in charge of the section where your doctor sent information about you when you were sick with diarrhoea (runny poos), or tummy pains or vomiting. This illness is called *Salmonella* infection, and people at the Health Department try to find out if others got sick. They want to know if people ate the same food that could have caused them to get sick.

You were sent this letter from Dr Koehler at the Health Department who knows your information; she sent it on my behalf because I can't see your information. If you would like to take part, your parent or carer will help you to fill in the questions. Some questions will be about you and some will be about what happens in your house on a hot day, your parent will fill that bit out. You should talk to your parents about the project too.

Only my supervisor and I will see your answers, but please don't worry as I won't know that the answers came from you as we are not asking you to give your name or any information that could tell us who you are. You can fill in the questions on the internet, or ring me and we can do it over the phone, or you can fill in the questions on paper. After the project is over, I will lock all the results away safely in the Discipline of Public Health for 5 years. I have to do this because it is a University rule. After this time they will be destroyed.

Remember, you don't have to take part unless you want to. If you have any questions you should talk to your parent or carer. If they don't know the answer to your questions, they can contact me (see below for my details), or the Research Ethics Officer at the Health Department (SA Health).

If you want to be part of the project, and your parent also agrees, please sign your name (if you can write) on the Consent Form where it says "Child or young person signature", and also get your Parent/Guardian to sign it as well.

My contact details are: Ms Adriana Milazzo

Discipline of Public Health  
Level 7, 178 North Terrace, Adelaide,  
School of Population Health  
The University of Adelaide 5000  
Ph) 8313 0199  
Email) [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au)

**Consent Form**  
**Parents/Guardians and Children/Young People**

**Date:** February 2013

**Full project title:** Food safety on hot days.

**Researchers:** Ms Adriana Milazzo, Professor Peng Bi and Dr Ying Zhang (Discipline of Public Health, School of Population Health, The University of Adelaide) and Dr Ann Koehler (Director, Communicable Disease Control Branch, SA Health).

---

**Please read below and tick the relevant statement if participating on behalf of your child:**

- I have read and understood the attached Information sheets (a copy for Children and a copy for Parents/Guardians)
- I freely consent to participate in this study according to the conditions in the Information Sheet
- I give permission for my child to participate in this study according to the conditions in the Information Sheet
- I have been given a copy of the Information and Consent Form to keep

The researchers have agreed not to reveal my identity and personal details, including where information about this study is published or presented in any public form.

**Parent/Guardian signature**..... **Date**.....

**Child or young person's signature**.....**Date**.....  
(if able to)

## **Appendix B: Food safety questionnaire**

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- Food safety questionnaire for *Campylobacter* cases
- Food safety questionnaire for *Salmonella* cases

### Survey: Food safety on hot days

The information you provide in this survey is to try and understand people's food shopping patterns, food preparation/storage and food preferences during hot weather. All information you provide is confidential and we cannot identify you or your child (if they had the *Campylobacter* infection). While your input to the survey is very important to us, participation is voluntary and you can choose not to answer any particular question or section and you are free to withdraw from the survey at any time.

**Do you give consent to participate in the survey?**

- Yes  No

This survey will take about 15 minutes to complete. There are 4 sections to this survey, please complete all sections if you are a parent/guardian of a child diagnosed with *Campylobacter* infection and completing the questionnaire on behalf of, or with the child OR Sections 1, 2 and 3 if you are the person with *Campylobacter*.

#### Section 1: Information about the person with *Campylobacter* infection

Q1 to Q8 in this section relate to the person diagnosed with *Campylobacter* infection.

**Q1. Which of the following age groups best describes you?**

- Less than 12 months  1 to 4 years  
 5 to 9 years  10 to 19 years  
 20 to 39 years  40 to 59 years  
 60 years or greater

**Q2. What is your sex?**

- Male  Female

**Q3. What is your country of birth?**

.....

**Q4. What is the main language spoken at home?**

.....

**Q5. What is your postcode of residence?**

.....

**Q6. Highest level of education you have reached?**

- Still at school/preschool  Primary  
 Part secondary  Completed secondary  
 Trade/Apprenticeship  Certificate/Diploma  
 Bachelor degree or higher  None

**Q7. Before tax is taken out, which of the following ranges best describes your household's income, from all sources, over the last 12 months?**

- Up to 12,000  \$12,001 - \$20,000  
 \$20,001 - \$30,000  \$30,001 - \$40,000  
 \$40,001 - \$50,000  \$50,001 - \$60,000  
 \$60,001 - \$80,000  \$80,001 - \$100,000  
 \$100,001 - \$150,000  \$150,001 - \$200,000  
 More than \$200,000  Don't know

**Q8. In general, how would you rate your health?**

- Very good  Good  
 Fair  Poor  Very poor

<b>Section 2: Food preparation</b>
------------------------------------

If the person who had the *Campylobacter* infection is a child, a parent/guardian should complete Q9 on behalf of, or with the child.

**Q9. How often do you do any of the following? Use the scale to select a response for each activity listed.**

	Always	Most of the time	Sometimes	Seldom	Never
Wash your hands after visiting the toilet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash your hands before handling food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash your hands before eating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw fruits before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw salads before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw vegetables before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q10. Who is the main person responsible for food shopping and food preparation in your household?**

- Parent                       Spouse/ partner                       Friend                       Self  
 Children                       No-one                       Other (Please specify)

.....

Q11 to Q25 are to be answered by the person diagnosed with *Campylobacter* infection or the main person in the household responsible for food shopping and food preparation.

**Q11. How often do you do the following when preparing food? Use the scale to select a response for each thing listed.**

	Always	Most of the time	Sometimes	Seldom	Never
Wash your hands after touching raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use separate cutting boards for just raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash cutting boards used for raw chicken/meat before using them for food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Put cooked meats back into same plates used to store raw chicken/meat without washing them first	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pour marinades that contained raw chicken/meat over cooked meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q12. What do you use to clean the cutting board after preparing raw meat?**

- Detergent and water                       Bleach and water  
 Dishwasher                       Plain water  
 Antibacterial cleaner/ disinfectant                       Vinegar or lemon juice  
 Don't prepare raw meat

**Q13. What do you usually do after handling raw meat?**

- Wash hands with soap & water                       Rinse hands  
 Continue cooking without washing hands                       Wipe hands  
 Don't handle raw meat

**Q14. What temperature range is your refrigerator set at?**

- 4°C to -1°C                       0°C to 5°C  
 6°C to 10°C                       Greater than 10°C  
 Don't know

**Q15. In your opinion how safe is it to do the following things in order to avoid food poisoning? Use the scale to select a response for each activity listed.**

	Very Safe	Safe	Neither safe nor unsafe	Unsafe	Very unsafe	Don't know
Wash your hands after touching raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use separate cutting boards for just raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash cutting boards used for raw chicken/meat before using them for food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Put cooked meats back into same plates used to store raw chicken/meat without washing them first	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pour marinades that contained raw chicken/meat over cooked meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q16. Which foods do you recognise as a risk factor for *Campylobacter* infection? Please select all that applies.**

- |  |  |  |  |
|--|--|--|--|
| <input type="checkbox"/> Raw chicken and other poultry | <input type="checkbox"/> Raw eggs          | <input type="checkbox"/> Raw meat          | <input type="checkbox"/> Undercooked meat      |
| <input type="checkbox"/> Undercooked chicken           | <input type="checkbox"/> Fish and seafood  | <input type="checkbox"/> Fresh fruit       | <input type="checkbox"/> Raw vegetables        |
| <input type="checkbox"/> Raw salads                    | <input type="checkbox"/> Pre-packed salads | <input type="checkbox"/> Fresh fruit juice | <input type="checkbox"/> Fresh vegetable juice |
| <input type="checkbox"/> Dairy                         | <input type="checkbox"/> Cream             | <input type="checkbox"/> Cream cakes       | <input type="checkbox"/> Don't know            |

### Section 3: Hot weather, food preparation and food shopping

**Q17. On hot days, is your household food shopping likely to be done at a shop closer to home compared to on cold days?**

- Yes  No  Don't know

**Q18. On hot days, how likely are you to do your household food shopping in the following locations than on colder days? Please select a response for each location listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Supermarket	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Butcher	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Poultry shop	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit & veg store	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ethnic food store	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Markets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Roadside stall	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q19. Usually, how long does it take you to travel home after food shopping?**

- |   |   |
|---|---|
| <input type="checkbox"/> Less than 15 minutes | <input type="checkbox"/> 20 to 30 minutes |
| <input type="checkbox"/> 31 to 45 minutes     | <input type="checkbox"/> 46 to 60 minutes |
| <input type="checkbox"/> More than 1 hour     |   |

**Q20. Are you likely to go straight home after you buy raw meat and fresh food on a hot day compared to a cold day?**

- Very likely  Likely  Neither likely nor unlikely  
 Unlikely  Not at all likely

Thank you for completing the survey

**Q21. On a hot day, how likely is raw meat and fresh food carried from shop to home using the following items than on cold days? Please select a response for each item listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Esky	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Insulated bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Plastic shopping bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Material shopping bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cardboard box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q22. On a hot day, how long would it take you to unpack raw meat and fresh food at home and to place in storage than on a cold day?**

- Less than 15 minutes       20 to 30 minutes  
 31 to 45 minutes       More than 1 hour  
 46 to 60 minutes

**Q23. Which of the following would you prefer to do to defrost frozen raw meat on a hot day than on a cold day?**

- Refrigerator       Microwave  
 Room temperature       Water  
 Cook meat frozen

*If you ticked room temperature go to Q24*

*If you did not tick room temperature go to Q25*

**Q24. When defrosting frozen raw meat at room temperature on a hot day, how long is it usually for?**

- Less than 2 hours       3 hours  
 4 hours       Longer than 4 hours

**Q25. Is your household likely to have a BBQ on hot days compared to cold days?**

- Very likely       Likely  
 Neither likely nor unlikely       Unlikely  
 Not at all likely

Q26 and Q27 are to be answered by the person diagnosed with *Campylobacter* infection.

**Q26. On a hot day are you likely to eat out at the following compared to on a cold day? Please select a response for each eating out options listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Cafe or restaurants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bakery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Takeaway/fast food outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Corner-store/deli	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Parties/functions with family	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Festivals or commercial public gatherings (e.g. fetes, clubs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q27. On a hot day, are you likely to eat the following foods than on a cold day? Please select a response for all food items listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Chicken	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Red or other meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fish/seafood	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eggs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smallgoods	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bagged ready to eat raw salad	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh vegetable juices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh fruit juices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh fruit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ice-cream	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cream cakes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q28 to Q30 are to be answered by the person diagnosed with *Campylobacter* infection or the main person in the household responsible for food shopping and food preparation.

**Q28. Do you feel that you receive adequate information about food safety on hot days?**

- Yes       No       Don't know

**Q30. How likely do you think heat is responsible for infectious diseases which can cause diarrhoea?**

- Very likely     Likely       Neither likely nor unlikely  
 Unlikely       Not at all likely     Don't know

**Q29. What is the best way for you to receive information about food safety on hot days, particularly during heat waves? Please select all that applies.**

- |  |   |
|--|---|
| <input type="checkbox"/> Local council | <input type="checkbox"/> Public lecture               |
| <input type="checkbox"/> Television    | <input type="checkbox"/> Internet                     |
| <input type="checkbox"/> School        | <input type="checkbox"/> Brochures/pamphlets          |
| <input type="checkbox"/> Radio         | <input type="checkbox"/> Health department            |
| <input type="checkbox"/> Other         | <input type="checkbox"/> Print media (e.g. newspaper) |

(Please specify)

.....

**Section 4: Information about the household member or parent/ guardian**

This section is only to be completed if you are not the person with *Campylobacter* infection (i.e. you are completing the survey on behalf of someone else).

**Q31. Are you:**     Male       Female

**Q34. Highest level of education you have reached?**

**Q32. Which of the following age groups best describes you?**

- |  |  |
|--|--|
| <input type="checkbox"/> Still at school           | <input type="checkbox"/> Primary               |
| <input type="checkbox"/> Part secondary            | <input type="checkbox"/> Completed secondary   |
| <input type="checkbox"/> Certificate/Diploma       | <input type="checkbox"/> Trade/ Apprenticeship |
| <input type="checkbox"/> Bachelor degree or higher | <input type="checkbox"/> None                  |

- |   |  |
|---|--|
| <input type="checkbox"/> 10 to 19 years | <input type="checkbox"/> 20 to 39 years      |
| <input type="checkbox"/> 40 to 59 years | <input type="checkbox"/> 60 years or greater |

**Q33. What is your country of birth?**

.....

**You have completed the survey. Thank you for participating, we appreciate your help.**

**Thank you for completing the survey**



### Survey: Food safety on hot days

The information you provide in this survey is to try and understand people's food shopping patterns, food preparation/storage and food preferences during hot weather. All information you provide is confidential and we cannot identify you or your child (if they had the *Salmonella* infection). While your input to the survey is very important to us, participation is voluntary and you can choose not to answer any particular question or section and you are free to withdraw from the survey at any time.

**Do you give consent to participate in the survey?**

Yes  No

This survey will take about 15 minutes to complete. There are 4 sections to this survey, please complete all sections if you are a parent/guardian of a child diagnosed with *Salmonella* infection and completing the questionnaire on behalf of, or with the child OR Sections 1, 2 and 3 if you are the person with *Salmonella*.

**Section 1: Information about the person with *Salmonella* infection**

Q1 to Q8 in this section relate to the person diagnosed with *Salmonella* infection.

**Q1. Which of the following age groups best describes you?**

Less than 12 months       1 to 4 years  
 5 to 9 years               10 to 19 years  
 20 to 39 years             40 to 59 years  
 60 years or greater

**Q2. What is your sex?**

Male  Female

**Q3. What is your country of birth?**

.....

**Q4. What is the main language spoken at home?**

.....

**Q5. What is your postcode of residence?**

.....

**Q6. Highest level of education you have reached?**

Still at school/preschool       Primary  
 Part secondary                 Completed secondary  
 Trade/Apprenticeship         Certificate/Diploma  
 Bachelor degree or higher     None

**Q7. Before tax is taken out, which of the following ranges best describes your household's income, from all sources, over the last 12 months?**

Up to 12,000                     \$12,001 - \$20,000  
 \$20,001 - \$30,000           \$30,001 - \$40,000  
 \$40,001 - \$50,000           \$50,001 - \$60,000  
 \$60,001 - \$80,000           \$80,001 - \$100,000  
 \$100,001 - \$150,000         \$150,001 - \$200,000  
 More than \$200,000         Don't know

**Q8. In general, how would you rate your health?**

Very good                       Good  
 Fair                                 Poor                       Very poor

**Thank you for completing the survey**

<b>Section 2: Food preparation</b>
------------------------------------

If the person who had the *Salmonella* infection is a child, a parent/guardian should complete Q9 on behalf of, or with the child.

**Q9. How often do you do any of the following? Use the scale to select a response for each activity listed.**

	Always	Most of the time	Sometimes	Seldom	Never
Wash your hands after visiting the toilet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash your hands before handling food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash your hands before eating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw fruits before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw salads before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash raw vegetables before eating them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q10. Who is the main person responsible for food shopping and food preparation in your household?**

- Parent
  Spouse/ partner
  Friend
  Self  
 Children
  No-one
  Other (Please specify)

.....

Q11 to Q25 are to be answered by the person diagnosed with *Salmonella* infection or the main person in the household responsible for food shopping and food preparation.

**Q11. How often do you do the following when preparing food? Use the scale to select a response for each thing listed.**

	Always	Most of the time	Sometimes	Seldom	Never
Wash your hands after touching raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use separate cutting boards for just raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash cutting boards used for raw chicken/meat before using them for food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Put cooked meats back into same plates used to store raw chicken/meat without washing them first	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pour marinades that contained raw chicken/meat over cooked meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q12. What do you use to clean the cutting board after preparing raw meat?**

- Detergent and water
  Bleach and water  
 Dishwasher
  Plain water  
 Antibacterial cleaner/ disinfectant
  Vinegar or lemon juice  
 Don't prepare raw meat

**Q13. What do you usually do after handling raw meat?**

- Wash hands with soap & water
  Rinse hands  
 Continue cooking without washing hands
  Wipe hands  
 Don't handle raw meat

**Q14. What temperature range is your refrigerator set at?**

- 4°C to -1°C
  0°C to 5°C  
 6°C to 10°C
  Greater than 10°C  
 Don't know

**Q15. In your opinion how safe is it to do the following things in order to avoid food poisoning? Use the scale to select a response for each activity listed.**

	Very Safe	Safe	Neither safe nor unsafe	Unsafe	Very unsafe	Don't know
Wash your hands after touching raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use separate cutting boards for just raw chicken/meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wash cutting boards used for raw chicken/meat before using them for food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Put cooked meats back into same plates used to store raw chicken/meat without washing them first	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pour marinades that contained raw chicken/meat over cooked meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q16. Which foods do you recognise as a risk factor for *Salmonella* infection? Please select all that applies.**

- |  |  |  |  |
|--|--|--|--|
| <input type="checkbox"/> Raw chicken and other poultry | <input type="checkbox"/> Raw eggs          | <input type="checkbox"/> Raw meat          | <input type="checkbox"/> Undercooked meat      |
| <input type="checkbox"/> Undercooked chicken           | <input type="checkbox"/> Fish and seafood  | <input type="checkbox"/> Fresh fruit       | <input type="checkbox"/> Raw vegetables        |
| <input type="checkbox"/> Raw salads                    | <input type="checkbox"/> Pre-packed salads | <input type="checkbox"/> Fresh fruit juice | <input type="checkbox"/> Fresh vegetable juice |
| <input type="checkbox"/> Dairy                         | <input type="checkbox"/> Cream             | <input type="checkbox"/> Cream cakes       | <input type="checkbox"/> Don't know            |

### Section 3: Hot weather, food preparation and food shopping

**Q17. On hot days, is your household food shopping likely to be done at a shop closer to home compared to on cold days?**

- Yes                       No                       Don't know

**Q18. On hot days, how likely are you to do your household food shopping in the following locations than on colder days? Please select a response for each location listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Supermarket	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Butcher	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Poultry shop	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit & veg store	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ethnic food store	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Markets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Roadside stall	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q19. Usually, how long does it take you to travel home after food shopping?**

- |   |   |
|---|---|
| <input type="checkbox"/> Less than 15 minutes | <input type="checkbox"/> 20 to 30 minutes |
| <input type="checkbox"/> 31 to 45 minutes     | <input type="checkbox"/> 46 to 60 minutes |
| <input type="checkbox"/> More than 1 hour     |   |

**Q20. Are you likely to go straight home after you buy raw meat and fresh food on a hot day compared to a cold day?**

- Very likely     Likely             Neither likely nor unlikely  
 Unlikely        Not at all likely

**Thank you for completing the survey**

**Q21. On a hot day, how likely is raw meat and fresh food carried from shop to home using the following items than on cold days? Please select a response for each item listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Esky	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Insulated bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Plastic shopping bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Material shopping bag	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cardboard box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q22. On a hot day, how long would it take you to unpack raw meat and fresh food at home and to place in storage than on a cold day?**

- Less than 15 minutes       20 to 30 minutes  
 31 to 45 minutes       More than 1 hour  
 46 to 60 minutes

**Q23. Which of the following would you prefer to do to defrost frozen raw meat on a hot day than on a cold day?**

- Refrigerator       Microwave  
 Room temperature       Water  
 Cook meat frozen

*If you ticked room temperature go to Q24*

*If you did not tick room temperature go to Q25*

**Q24. When defrosting frozen raw meat at room temperature on a hot day, how long is it usually for?**

- Less than 2 hours       3 hours  
 4 hours       Longer than 4 hours

**Q25. Is your household likely to have a BBQ on hot days compared to cold days?**

- Very likely       Likely  
 Neither likely nor unlikely       Unlikely  
 Not at all likely

Q26 and Q27 are to be answered by the person diagnosed with *Salmonella* infection.

**Q26. On a hot day are you likely to eat out at the following compared to on a cold day? Please select a response for each eating out options listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Cafe or restaurants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bakery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Takeaway/fast food outlets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Corner-store/deli	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Parties/functions with family	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Festivals or commercial public gatherings (e.g. fetes, clubs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Q27. On a hot day, are you likely to eat the following foods than on a cold day? Please select a response for all food items listed.**

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Chicken	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Red or other meat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fish/seafood	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Eggs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smallgoods	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bagged ready to eat raw salad	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh vegetable juices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh fruit juices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh fruit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ice-cream	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cream cakes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q28 to Q30 are to be answered by the person diagnosed with *Salmonella* infection or the main person in the household responsible for food shopping and food preparation.

**Q28. Do you feel that you receive adequate information about food safety on hot days?**

- Yes       No       Don't know

**Q30. How likely do you think heat is responsible for infectious diseases which can cause diarrhoea?**

- Very likely     Likely       Neither likely nor unlikely  
 Unlikely       Not at all likely     Don't know

**Q29. What is the best way for you to receive information about food safety on hot days, particularly during heat waves? Please select all that applies.**

- |  |   |
|--|---|
| <input type="checkbox"/> Local council | <input type="checkbox"/> Public lecture               |
| <input type="checkbox"/> Television    | <input type="checkbox"/> Internet                     |
| <input type="checkbox"/> School        | <input type="checkbox"/> Brochures/pamphlets          |
| <input type="checkbox"/> Radio         | <input type="checkbox"/> Health department            |
| <input type="checkbox"/> Other         | <input type="checkbox"/> Print media (e.g. newspaper) |

(Please specify)

.....

**Section 4: Information about the household member or parent/ guardian**

This section is only to be completed if you are not the person with *Salmonella* infection (i.e. you are completing the survey on behalf of someone else).

**Q31. Are you:**     Male       Female

**Q34. Highest level of education you have reached?**

**Q32. Which of the following age groups best describes you?**

- |  |  |
|--|--|
| <input type="checkbox"/> Still at school           | <input type="checkbox"/> Primary               |
| <input type="checkbox"/> Part secondary            | <input type="checkbox"/> Completed secondary   |
| <input type="checkbox"/> Certificate/Diploma       | <input type="checkbox"/> Trade/ Apprenticeship |
| <input type="checkbox"/> Bachelor degree or higher | <input type="checkbox"/> None                  |

- |   |  |
|---|--|
| <input type="checkbox"/> 10 to 19 years | <input type="checkbox"/> 20 to 39 years      |
| <input type="checkbox"/> 40 to 59 years | <input type="checkbox"/> 60 years or greater |

**Q33. What is your country of birth?**

.....

**You have completed the survey. Thank you for participating, we appreciate your help.**

**Thank you for completing the survey**

## **Appendix C: Ethics approval for food safety survey**

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- SA Health ethics approval letter
- SA Health ethics amendment and approval email
- Food safety survey telephone script



SA Health Human Research Ethics Committee  
Level 10, Citi-Centre Building  
11 Hindmarsh Square  
ADELAIDE SA 5000  
Telephone: (08) 8226 6367  
Facsimile: (08) 8226 7088

Ms Adriana Milazzo  
Discipline of Public Health  
University of Adelaide  
Level 7, 178 North Terrace  
ADELAIDE SA 5005

Dear Ms Milazzo,

**HREC reference number:** HREC/12/SAH/93

**Project title:** Food safety on hot days: Knowledge, attitudes and practices

**RE: HREC Application – Approval**

Thank you for responding to the issues raised by the SA Health HREC in relation to the above project.

I am pleased to advise that your application has been granted full ethics approval and appears to meet the requirements of the *National Statement on Ethical Conduct in Human Research*.

Please note the following conditions of approval:

- The research must be conducted in accordance with the 'National Statement on Ethical Conduct in Human Research.'
- A progress report, at least annually, must be provided to the HREC.
- When the project is completed, a final report must be provided to the HREC.
- The HREC must be notified of any complaints by participants or of adverse events involving participants.
- The HREC must be notified immediately of any unforeseen events that might affect ethical acceptability of the project.
- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.

HREC approval is valid for 3 years from the date of this letter.

Should you have any queries about the HREC's consideration of your project please contact Sarah Lawson, Executive Officer of the HREC, on (08) 8226 6367 or [hrec@health.sa.gov.au](mailto:hrec@health.sa.gov.au)

**You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a SA Health site until separate authorisation from the Chief Executive or delegate of that site has been obtained via the completion of a Site Specific Assessment form. Please contact David van der Hoek via email at [ResearchGovernance@health.sa.gov.au](mailto:ResearchGovernance@health.sa.gov.au) to discuss this process further.**

The HREC wishes you every success in your research.

Yours sincerely

**Rebecca Horgan  
CHAIRPERSON  
HUMAN RESEARCH ETHICS COMMITTEE**

**19/12/12**



**Amendment to HREC12SAH93 – confirmation email**

**From:** Lawson, Sarah (Health) [mailto:Sarah.Lawson@health.sa.gov.au]  
**Sent:** Friday, 15 March 2013 4:46 PM  
**To:** Adriana Milazzo <adriana.milazzo@adelaide.edu.au>  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Adriana,  
The Chair has approved the script – please accept this email as notification of this approval.  
Kind regards,  
Sarah

**From:** Adriana Milazzo [mailto:adriana.milazzo@adelaide.edu.au]  
**Sent:** Thursday, 14 March 2013 2:02 PM  
**To:** Lawson, Sarah (Health)  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Sarah

Here is an updated telephone script.

Thank you

Adriana

Adriana Milazzo

**From:** Lawson, Sarah (Health) [mailto:Sarah.Lawson@health.sa.gov.au]  
**Sent:** Thursday, 14 March 2013 10:45 AM  
**To:** Adriana Milazzo  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Adriana,  
I have sent your email to the A/Chair of the HREC. I am not sure of his availability to review this today/tomorrow but hopefully I will be able to get back to you by early next week.  
Cheers  
Sarah

**From:** Adriana Milazzo [mailto:adriana.milazzo@adelaide.edu.au]  
**Sent:** Thursday, 14 March 2013 10:29 AM  
**To:** Lawson, Sarah (Health)  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Sarah

Please find attached a copy of the telephone script and a revised questionnaire – the changes have been made based on the initial 18 completed surveys – I haven't included any new questions – more streamlining and ensuring the questions were clear and taking some questions out as it was long. CDCB are able to start follow up with cases next week –

would it possible for the telephone script to be approved by early next week? The 2 questionnaires are exactly the same – one is sent to *Campylobacter* cases and the other to *Salmonella* cases.

Thanks for your help

Regards  
Adriana

Adriana Milazzo

**From:** Lawson, Sarah (Health) [<mailto:Sarah.Lawson@health.sa.gov.au>]  
**Sent:** Thursday, 28 February 2013 2:59 PM  
**To:** Adriana Milazzo  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Adriana,  
The Chair is happy to approve this change in recruitment, subject to you providing us with a copy of the script that the CDCB staff will use when ringing potential participants.  
Thanks  
Sarah

**From:** Adriana Milazzo [<mailto:adriana.milazzo@adelaide.edu.au>]  
**Sent:** Thursday, 28 February 2013 12:23 PM  
**To:** Lawson, Sarah (Health)  
**Subject:** RE: Amendment to HREC/12/SAH/93

Hi Sarah

Just wondering if you have a chance to follow up with the A/Chair re recruitment.

Thanks  
Adriana

Adriana Milazzo

**From:** Lawson, Sarah (Health) [<mailto:Sarah.Lawson@health.sa.gov.au>]  
**Sent:** Wednesday, 20 February 2013 11:19 AM  
**To:** Adriana Milazzo  
**Subject:** RE: Amendment to HREC/12/SAH/93

Thanks Adriana,  
I will follow this up with the A/Chair and provide you with a response.  
Cheers  
Sarah

**From:** Adriana Milazzo [<mailto:adriana.milazzo@adelaide.edu.au>]  
**Sent:** Monday, 18 February 2013 11:06 AM  
**To:** Lawson, Sarah (Health)  
**Cc:** Koehler, Ann (Health)  
**Subject:** Amendment to HREC/12/SAH/93

Dear Sarah

I would like to obtain approval to change the process of recruitment for study participants as detailed in the original ethics application – HREC/12/SAH/93, Project: Food safety on hot days: Knowledge, attitudes and practices.

Recruitment of participants

Participant's responses to the survey have been poor – of the 86 invitation letters sent out, including hard copy questionnaire and link to on-line survey, only 19 have responded.

To increase the response rate it is proposed that CDCB staff will follow up participants 2 weeks after they have received the initial letter (inviting participants to take part in the study) by telephone.

Kind regards  
Adriana

Adriana Milazzo  
Lecturer  
Discipline of Public Health  
Level 7, 178 North Tce  
School of Population Health  
The University of Adelaide, AUSTRALIA 5005

Ph: +61 8 8313 0199  
e-mail: [adriana.milazzo@adelaide.edu.au](mailto:adriana.milazzo@adelaide.edu.au)  
<http://www.health.adelaide.edu.au/publichealth>

### Food safety survey Telephone script

#### Introduction

“Good..... my name is ..... I’m calling on behalf of SA Health, could I please speak with ..... (name of adult case diagnosed with *Salmonella* or *Campylobacter* infection) or the parent/guardian of ..... (child/young person diagnosed with *Salmonella* or *Campylobacter* infection)”.

#### If the person is not home:

“Do you know when would be a suitable time to call back to speak with .....”  
“Thank you for your time”

#### If the person is home:

We are conducting a survey on people who were recently diagnosed with .....(*Salmonella*) or ..... (*Campylobacter*) infection about their food shopping patterns, food preparation and storage and food preferences during hot weather. We recently sent you a letter about the survey which we are conducting in conjunction with The Adelaide University.

Did you receive the letter?

1. Yes
2. No
3. Don't know

#### Interviewer note: If respondent did not receive letter, offer to read the following:

“The survey is conducted by SA Health and is a joint project with The University of Adelaide. The information you provide in this survey is to try and understand people’s food shopping patterns, food preparation/storage and food preferences during hot weather. There is no right or wrong answers to the questions. So, please, provide answers that reflect you personal opinion and your household practices.

We have your contact details because your doctor recently notified you (if adult case) or your child’s (if parent/guardian of child) infection to the Communicable Disease Control Branch (CDCB), SA Health which he/she is legally required to do. I can assure you that all information given will remain confidential. The answers from all people interviewed will be gathered together and presented in a report. No individual answers will be passed on.

The questionnaire will take approximately 15 minutes to complete.

Whilst your input to the survey is very important to us, participation is voluntary and you can choose not to answer any particular question or any section and you are free to withdraw from the survey at any time.

Please be mindful that SA Health may also need to contact you as part of their routine investigation of foodborne diseases which include *Campylobacter* and *Salmonella* infection.

**Are you willing to participate in this survey by telephone?**

**Yes, willing to participate**

a) "Is now a good time for you"?

- If participant responds "Yes" – please proceed with survey

b) If participant responds yes, but not now

- "When is a convenient time and day for me to call back to complete the survey with you over the phone"? (Set up a date and time for the interview)
- "There may be times when I am unable to call back – if this is the case, do you give permission for your contact details to be given to Ms Adriana Milazzo, Principal Researcher of the study at The Adelaide University to conduct the survey with you by phone"?
- If the participant does not give permission:
- "That's quite alright, you can be assured that your contact details will not be given to The University of Adelaide and that I will phone you back at ..... (time) on the .....(date)

c) If the participant would like to respond but they don't have time

- "Do you have an email address? If you prefer I can send you an email with the survey link for you to complete it on-line"?

**No, not willing to participate in the survey:**

"Thank you for your time"

**After completion of the survey by telephone**

That concludes the survey.

On behalf of SA Health and The University of Adelaide, thank you very much for taking part in this survey. Are there any questions that you would like to ask?

## **Appendix D: Ethics approval for analysis of *Salmonella* and *Campylobacter* notification data**

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- Adelaide University ethics approval letter
- SA Health ethics approval letter



RESEARCH BRANCH  
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND  
INTEGRITY

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CRICOS Provider Number 00123M

15 August 2012

Professor P Bi  
Discipline of Public Health, The University of Adelaide

Dear Professor Bi

**PROJECT NO: H-202-2011**

***The relationship between heat waves and the incidence of foodborne illness in a temperate climate***

Thank you for your report on the above project. I write to advise you that I have endorsed renewal of ethical approval for the study on behalf of the Human Research Ethics Committee.

**The expiry date for this project is: 31 August 2015**

Where possible, participants taking part in the study should be given a copy of the Information Sheet and the signed Consent Form to retain.

Please note that any changes to the project which might affect its continued ethical acceptability will invalidate the project's approval. In such cases an amended protocol must be submitted to the Committee for further approval. It is a condition of approval that you immediately report anything which might warrant review of ethical approval including (a) serious or unexpected adverse effects on participants (b) proposed changes in the protocol; and (c) unforeseen events that might affect continued ethical acceptability of the project. It is also a condition of approval that you inform the Committee, giving reasons, if the project is discontinued before the expected date of completion.

A reporting form is available from the Committee's website. This may be used to renew ethical approval or report on project status including completion.

Yours sincerely

**Dr John Semmler**  
**Acting Convenor**  
**Human Research Ethics Committee**



SA Health Human Research Ethics Committee  
Level 10, Citi-Centre Building  
11 Hindmarsh Square  
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Ms Adriana Milazzo  
Discipline of Public Health  
University of Adelaide  
Terrace Towers  
Level 7, 178 North Terrace  
ADELAIDE SA 5005

Dear Ms Milazzo,

**HREC reference number:** 463.07.2014

**Project title:** The relationship between heat waves and the incidence of foodborne illness in a temperate climate.

Thank you for submitting a modification request in relation to the above project, namely to extend the study period to include 2011 and 2012 and include additional data fields. This was considered by the Chairperson of the SA Health Human Research Ethics Committee out-of-session.

I am pleased to advise that ethics approval has been granted to your modification request.

Please note that all original conditions of ethics approval continue to apply.

Should you have any questions or concerns, please contact Lauren Perry, Executive Officer of the HREC, phone (08) 8226 6431 or e-mail [hrec@health.sa.gov.au](mailto:hrec@health.sa.gov.au)

We wish you well with your research.

Yours sincerely,

**Dr David Filby**  
**CHAIRPERSON**  
**HUMAN RESEARCH ETHICS COMMITTEE**

**11/6/2013**