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

Adriana Milazzo, School of Public Health
The effect of temperature on different *Salmonella* serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia

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**Heatwaves differentially affect risk of *Salmonella* serotypes**

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**Summary**

Campylobacter spp. is a commonly reported food-borne disease with major consequences for morbidity. In conjunction with predicted increases in temperature, proliferation in the survival of microorganisms in hotter environments is expected. This is likely to lead, in turn, to an increase in contamination of food and water and a rise numbers of cases of infectious gastroenteritis. This study assessed the relationship of Campylobacter spp. with temperature and heatwaves, in Adelaide, South Australia.

We estimated the effect of (i) maximum temperature and (ii) heatwaves on daily Campylobacter cases during the warm seasons (1 October to 31 March) from 1990 to 2012 using Poisson regression models.
Burden of *Salmonella* and *Campylobacter* infection

- *Salmonella* & *Campylobacter* spp are bacterial infectious gastrointestinal illnesses, & most frequently reported causes of foodborne disease worldwide
- In Australia, account for a large proportion of burden of illness
  - *Salmonella* 54.1 DALY per 1000 cases per year
  - *Campylobacter* 23.5 DALY per 1000 cases per year
- In South Australia
  - 600-1,000 *Salmonella* cases reported annually
  - *Salmonella* notifications accounted for 35% of all notified gastrointestinal infections in 2014
  - 1,700-2,000 *Campylobacter* cases are reported annually
  - *Campylobacter* notifications accounted for 52% of all notified gastrointestinal infections in 2014
- Changes in climate through increasing warmer ambient temperature considered to be contributing factors to foodborne diseases
Adelaide and a changing climate

Adelaide

- Estimated population of 1.3 million
- Temperate climate with mild winters and warm, dry summers

Increase in warmer temperature

- “Hotter, longer and more often”
- SA current average number of days over 35°C is 17 days
- By 2030 increase to 21-26 days
Evidence and knowledge gap

• Human behaviour in response to warmer weather eg. changes in people’s eating behaviours, food preferences & food safety practices
• Association exists between ambient temperature & *Salmonella* infection
• Are different *Salmonella* serotypes & phage types affected differentially by temperature
• Relationship between *Campylobacter* infection & temperature is less clear
• Little focus on associations during the warm seasons & identification of temperature thresholds
• Effects of heatwaves on the number of *Salmonella* & *Campylobacter* cases limited
Aims

• To assess food safety practices, food shopping preferences & eating behaviours of people diagnosed with *Salmonella* or *Campylobacter* infection in warm seasons, & to identify if socioeconomic status is associated with their behaviour & practices;

• To examine relationship between warmer ambient temperature & incidence of *Salmonella* & serotypes;

• To examine relationship between heatwaves & the incidence of *Salmonella* & serotypes;
Study framework

Part 1 (study 1)
Food safety knowledge, practices and preferences in warm weather: Survey of Salmonella and Campylobacter cases January to March 2013

Notifiable Disease Data

Recommendations for foodborne prevention in warm weather and during heatwaves

Part 2 (studies 2-4)
Association between daily maximum temperature in warm season and heatwaves and Salmonella and Campylobacter cases 1990 to 2012

Meteorological

University of Adelaide
Methods & analysis: Food safety survey

• Cross-sectional survey
  – knowledge, behaviour & perceptions related to food safety

• Bivariate and multivariable logistic regression analyses
  – examined relationship between food safety practices, behaviour, & knowledge with individual demographic characteristics, & socioeconomic status
  • income, education and level of socioeconomic disadvantage
Analysis: temperature and heatwaves

• Daily *Salmonella*, serotype & *Campylobacter* counts
  • warm season October to March
  • heatwave definition - daily maximum temperature reaches or surpasses 3 or more consecutive days of 35°C
• Serotypes based on the 5 ranked with the highest frequency over the study period
• Exposure–response relationship between counts & maximum temperature
  – plots visually inspected for temperature thresholds
  – piecewise linear regression models fitted
• Time-series Poisson regression
  – lag values included
  – foodborne outbreaks excluded
• GEE and DLNM
  – assessing associations simultaneously accounting for non-linear effects of temperature & lagged effects over time
Factors Influencing Knowledge, Food Safety Practices and Food Preferences During Warm Weather of *Salmonella* and *Campylobacter* Cases in South Australia

Adriana Milazzo, Lynne C. Giles, Ying Zhang, Ann P. Koehler, Janet E. Hiller, and Peng Bi
Survey questionnaire

• Demographic characteristics
• Questions related to food safety within three broad domains
  – (1) knowledge and behaviour in safe food handling practices;
  – (2) behaviour and preferences for shopping, eating out, and specific foods eaten on warm days,
  – (3) preferences and perceptions about receiving food safety information on warm days, and knowledge about heat as a risk factor for infectious gastroenteritis
### Participant characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (n=180)</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 9</td>
<td>21 (12)</td>
</tr>
<tr>
<td>10 - 19</td>
<td>16 (9)</td>
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<tr>
<td>20 - 39</td>
<td>40 (22)</td>
</tr>
<tr>
<td>40 - 59</td>
<td>53 (29)</td>
</tr>
<tr>
<td>60+</td>
<td>50 (28)</td>
</tr>
<tr>
<td><strong>Gender (n=173)</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>73 (42)</td>
</tr>
<tr>
<td>Female</td>
<td>100 (58)</td>
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<tr>
<td><strong>Education (n=169)</strong></td>
<td></td>
</tr>
<tr>
<td>At school</td>
<td>20 (12)</td>
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<tr>
<td>Primary, part secondary school</td>
<td>29 (17)</td>
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<tr>
<td>Secondary school, trade</td>
<td>44 (26)</td>
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<tr>
<td>Certificate, diploma, degree</td>
<td>76 (45)</td>
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<tr>
<td><strong>Annual household income (n=168)</strong></td>
<td></td>
</tr>
<tr>
<td>Up to $30,000</td>
<td>32 (19)</td>
</tr>
<tr>
<td>$30,001 - $60,000</td>
<td>38 (22)</td>
</tr>
<tr>
<td>&gt; $60,000</td>
<td>80 (47)</td>
</tr>
<tr>
<td>Unknown</td>
<td>18 (12)</td>
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<tr>
<td><strong>Index of Relative Socio-Economic Disadvantage (n=180)</strong></td>
<td></td>
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<tr>
<td>Lowest quintile</td>
<td>38 (21)</td>
</tr>
<tr>
<td>Low quintile</td>
<td>35 (20)</td>
</tr>
<tr>
<td>Middle quintile</td>
<td>29 (16)</td>
</tr>
<tr>
<td>High quintile</td>
<td>36 (20)</td>
</tr>
<tr>
<td>Highest quintile</td>
<td>42 (23)</td>
</tr>
</tbody>
</table>
Food safety practices

**Food preparation**
- 12% carried out unsafe food practices
- 70% used separate cutting boards for raw meat only
- 80% always washed cutting boards prior to use for food, & after preparation of raw meat
- Detergent (78%) commonly used for washing cutting boards after preparing raw meat
  - wash cutting boards using vinegar (3%) & plain water (3%)

**Preferences for defrosting raw frozen meat (warm days)**
- 57% refrigerator, 13% microwave, 1% of preferred water & cooking frozen meat
- 28% room temperature
  - 43% >2 hours, 28% took >4 hours
Food safety practices

Shopping practices (warm days)

- 88% of respondents more likely to go directly home after food shopping
- 76% likely to carry food in insulated shopping bags
- 93% took less than 15 minutes to unpack raw meat/fresh food & place in storage
Food and shopping preferences

Eating out & BBQ (warm days)

- 45% parties, 35% cafes, 30% takeaway preferred
- 54% of households likely to have a barbeque

Age
- 60+ years less likely to eat out at festival events (OR 0.25, 95% CI 0.07-0.84)
- have barbeque on warm days (OR 0.14, 95% CI 0.05-0.42)

Consumption of high risk foods (warm day)

Social disadvantage
- most disadvantaged more likely to eat chicken (OR 4.12, 95% CI 1.49-11.33) & vegetables (OR 3.59, 95% CI 1.24-10.34)

Age
- 60+ years more likely to eat eggs (OR 6.44, 95% CI 1.87-22.19)

Overall
- 44% consumed high-risk foods on a warm day
  - 72% fruit, 64% ice-cream, 59% vegetables, 52% chicken, 49% fish, 40% eggs
Knowledge

**High risk foods**
- 25% had poor knowledge about high-risk foods for foodborne infection
  Foods considered high-risk
  - 92% undercooked chicken, 90% raw chicken, 75% raw meat, 70% undercooked meat, 55% fish, 41% raw eggs, 34% dairy, 27% pre-packed salads

**Correct refrigerator temperature setting**
- not known by 49% of respondents
- females were twice as likely as males to know the correct setting (OR 2.26, 95% CI 1.09-4.71)
## Information about food safety

**Socio-demographic characteristics**

<table>
<thead>
<tr>
<th>TV preference for receiving information (n=107)</th>
<th>Internet preference for receiving information (n=60)</th>
<th>Print preference for receiving information (n=73)</th>
<th>Radio preference for receiving information (n=48)</th>
<th>Health department preference for receiving information (n=38)</th>
<th>Local council preference for receiving information (n=22)</th>
<th>School preference for receiving information (n=32)</th>
<th>Pamphlets preference for receiving information (n=58)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
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<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
<td>OR (95% CI)</td>
</tr>
</tbody>
</table>

**Age**

| 20-39 (Referent) | 1.0 |
| 40 - 59 | 1.4 (0.59-3.52) | 0.9 (0.38-2.27) | 0.7 (0.29-1.70) | 1.0 (0.38-2.87) | 0.4 (0.14-1.22) | 0.3 (0.09-1.26) | 0.3 (0.07-1.41) | 0.5 (0.20-1.29) |
| 60+ | 1.2 (0.48-2.97) | 0.3 (0.13-0.94) | 1.6 (0.67-3.95) | 1.3 (0.51-3.64) | 0.2 (0.08-0.85) | 0.3 (0.08-1.17) | 0.3 (0.00-1.52) | 0.4 (0.18-1.20) |

**Gender**

| Female | 2.3 (1.15-4.87) | 1.2 (0.56-2.66) | 1.3 (0.64-2.72) | 0.6 (0.27-1.34) | 0.3 (0.13-0.84) | 0.7 (0.26-2.33) | 0.1 (0.00-0.41) | 0.7 (0.34-1.59) |
| Males (Referent) | 1.0 |

**Index of Relative Socio-Economic Disadvantage**

| Lowest quintile (Most disadvantaged) | 1.4 (0.00-4.42) | 0.2 (0.07-0.92) | 0.3 (0.10-0.98) | 0.5 (0.15-1.82) | 0.7 (0.19-3.25) | 1.6 (0.36-7.81) | 0.4 (0.04-5.30) | 0.8 (0.24-2.75) |
| Low quintile | 0.7 (0.27-2.28) | 0.3 (0.11-1.08) | 0.4 (0.16-1.40) | 0.7 (0.22-2.21) | 1.5 (0.04-5.35) | 1.3 (0.30-6.45) | 1.2 (0.01-7.57) | 1.4 (0.47-4.30) |
| Middle quintile | 1.0 (0.32-3.18) | 0.4 (0.14-1.48) | 0.4 (0.13-1.32) | 0.3 (0.08-1.47) | 0.4 (0.09-2.18) | 0.3 (0.03-3.01) | 1.9 (0.32-11.38) | 1.0 (0.31-3.49) |
| High quintile | 1.4 (0.52-4.19) | 0.6 (0.22-1.78) | 0.4 (0.16-1.26) | 1.5 (0.54-4.22) | 1.0 (0.28-3.61) | 1.1 (0.24-5.05) | 2.0 (0.36-11.42) | 0.8 (0.27-2.52) |
| Highest quintile (Referent) (Least disadvantaged) | 1.0 |

**Age – in the analysis age was restricted to include the 20-39, 40-59 and 60+ year age groups.**
Daily maximum temperature ($T_{\text{max}}$) by season and percentile, 1990 to 2012, Adelaide

<table>
<thead>
<tr>
<th>Time period</th>
<th>Maximum temperature ($T_{\text{max}}$)</th>
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<tr>
<td></td>
<td>Mean</td>
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<tr>
<td>1990 – 2012$^a$</td>
<td>22.3°C</td>
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<tr>
<td>Cool$^b$</td>
<td>18.2°C</td>
</tr>
<tr>
<td>Warm$^c$</td>
<td>26.5°C</td>
</tr>
<tr>
<td>Heatwaves$^d$</td>
<td>38.4°C</td>
</tr>
</tbody>
</table>

$^a$Salmonella cases (n=7845) notified in the study period.
$^b$Salmonella cases (n=3433) notified in the cool season (April to September).
$^c$Salmonella cases (n=4412) notified in the warm season (October to March).
$^d$Salmonella cases (n=238) notified during heatwaves.
The effect of temperature on different *Salmonella* serotypes during warm seasons in a Mediterranean climate city, Adelaide, Australia

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<tbody>
<tr>
<td>Month</td>
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<tbody>
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<td>Month</td>
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<tbody>
<tr>
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<thead>
<tr>
<th>Year</th>
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<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
<td></td>
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</tr>
</tbody>
</table>
Temperature thresholds

Salmonella 38.5°C (95% CI 35.9-41.0, p <0.01)  
STM9 39.2°C (95% CI 34.5-43.8, p <0.01)

STM108 39.3°C (95% CI 36.8-41.7, p <0.01)  
STM135 34.9°C (95% CI 29.3-40.4, p <0.01)
Daily number of *Salmonella* spp. serotype and phage type notifications reported in the warm season (October-March) per 1°C increase in maximum temperature, 1990-2012, Adelaide, South Australia.

<table>
<thead>
<tr>
<th>Serotype</th>
<th>Variables</th>
<th>Lag day</th>
<th>IRR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella</em> spp.</td>
<td>AR</td>
<td>3</td>
<td>1.061</td>
<td>1.033-1.089</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>$T_{\text{max}}$</td>
<td>14</td>
<td>1.013</td>
<td>1.008-1.019</td>
<td>0.001</td>
</tr>
<tr>
<td><em>S</em>.Typhimurium PT9</td>
<td>AR</td>
<td>1</td>
<td>1.295</td>
<td>1.094-1.533</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>$T_{\text{max}}$</td>
<td>14</td>
<td>1.037</td>
<td>1.020-1.053</td>
<td>0.001</td>
</tr>
<tr>
<td><em>S</em>.Typhimurium PT108</td>
<td>AR</td>
<td>8</td>
<td>1.640</td>
<td>1.224-2.190</td>
<td>0.001</td>
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<tr>
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<td>$T_{\text{max}}$</td>
<td>5</td>
<td>1.040</td>
<td>1.015-1.065</td>
<td>0.001</td>
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<tr>
<td><em>S</em>.Typhimurium PT135</td>
<td>AR</td>
<td>3</td>
<td>1.647</td>
<td>1.126-2.409</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>$T_{\text{max}}$</td>
<td>16</td>
<td>1.034</td>
<td>1.008-1.061</td>
<td>0.009</td>
</tr>
<tr>
<td><em>S</em>.Typhimurium PT44</td>
<td>AR</td>
<td>3</td>
<td>1.580</td>
<td>1.280-1.951</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>$T_{\text{max}}$</td>
<td>20</td>
<td>1.004</td>
<td>0.980-1.028</td>
<td>0.718</td>
</tr>
<tr>
<td><em>S</em>.Infantis</td>
<td>AR</td>
<td>3</td>
<td>1.923</td>
<td>1.459-2.534</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>$T_{\text{max}}$</td>
<td>14</td>
<td>1.044</td>
<td>1.024-1.064</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Autoregressive order (AR), Incidence Rate Ratio (IRR), 95% Confidence Interval (CI), p-value (0.05 significance level).
Heatwaves differentially affect risk of *Salmonella* serotypes

Adriana Milazzo\(^a,\)\(^*,\) Lynne C. Giles\(^a\), Ying Zhang\(^a,b\), Ann P. Koehler\(^c\), Janet E. Hiller\(^a,d\), Peng Bi\(^a,\)\(^**\)

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Accepted 20 April 2016  
Available online 15 June 2016
Effect estimates of heatwaves for all notified *Salmonella* cases and specific serotype and phage types, 1990-2012, Adelaide
Heatwave characteristics

• **Intensity**
  – examined by daily $T_{\text{max}}$ within heatwaves with four temperature ranges (35-36.9°C, 37-38.9°C, 39-40.9°C, ≥ 41°C)

• **Duration**
  – 3, 4 & 5+ days
  – alternative definition to examine the effect of short (3 days) compared to long duration (4+ days)

• **Timing**
  – defined by the 1st, 2nd, 3rd heatwave event within each warm season denoting the order of occurrence
  – differed by whether the heatwave event occurred in the early part of the warm season (October to December) or later (January to March)
Effect of heatwave characteristics on *Salmonella*

- Heatwave intensity had a greater impact on daily *Salmonella* infections
  - 34% increase (IRR 1.34, 95% CI 1.01-1.78) in *Salmonella* cases estimated if $T_{\text{max}}$ was $\geq 41^\circ\text{C}$
  - *Salmonella* cases less frequent in the early months of the warm season compared to the later months
Effect of heatwave characteristics on *Salmonella* serotypes

- **Risk by day**
  - twofold increase in risk on day 3 (IRR 2.09, 95% CI 1.04-4.20)
  - greater increase on day 5 (IRR 2.72, 95% CI 1.20-6.12) for *S*.Typhimurium PT135
- **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
- **Duration**
  - short duration increased risk twofold for *S*.Typhimurium PT135 (IRR 2.10, 95% CI 1.05-4.20) & duration by length of days had effects at 4 (IRR 3.30, 95% CI 1.34-8.13) and 5 days (IRR 2.47, 95% CI 1.04-5.88).
  - 4 day duration increased *S*.Infantis notifications close to threefold (IRR 2.84, 95% CI 1.26-6.41)
- **Timing**
  - increase in *S*.Typhimurium PT135 infections estimated with the 2nd heatwave event in the season (IRR 2.53, 95% CI 1.07-6.01), and a much higher risk in the 3rd (IRR 4.24, 95% CI 2.19-8.22)
  - 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
Discussion

- Development of food safety awareness in hot weather for domestic households, as well as for commercial food retailers.
- Community level education, health promotion and awareness raising are critical & could be incorporated as part of an early warning system at the start of heatwave events.
- Temperature thresholds can be useful in providing evidence for the development of early heat warning systems and alerts.
- The delayed effect of temperature on foodborne disease is important as it can indicate the timing at which the food chain contamination has occurred.
  - Short lag times with temperature points to food contamination closer to the time of consumption.
  - Longer time lags indicate effects at production processing stages.
  - Effective measures to reduce risk of foodborne disease can be implemented at any stage along the food chain.
- Possible source specific strains could be related to seasons and climate.
Significance

This study has wide applicability for heat-related foodborne disease prevention in the policy arena, including practical public health interventions at a local level with international adaptability.