Geographic variations in public perceptions & responses to heat & heatwave warnings

A thesis submitted in partial fulfilment of the HONOURS DEGREE of BACHELOR OF HEALTH SCIENCES

In

The School of Public Health
Faculty of Health Sciences
The University of Adelaide

By

Anna Wolanin

October 2016

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text. I give permission for my thesis to be reproduced and submitted to academic staff for the purpose of assessment.

Name: Anna Wolanin

Signed: AWolanin

Date: 10/2016

ABSTRACT

Introduction: One of the most dangerous natural hazards for population health in Australia is extreme heat, particularly for vulnerable groups. Excessive and prolonged exposure to heat can cause heat stroke, heat exhaustion, heat syncope, heat cramps, and exacerbate a number of medical conditions. The experiences of regional and rural populations is an underrepresented issue in the literature on heatwaves, and there is very little research that focuses on comparisons between differing climate regions. This study aims to examine attitudes and perceptions to extreme heat and heat warnings in regional South Australia, and how this may be influenced by climate region. Understanding how populations in diverse regional areas understand and perceive their risk is vital in understanding where public health action and policy must be aimed.

Methods: Existing data from a householder survey conducted in non-metropolitan South Australia (*n=251)* was analysed using Pearson's Chi-Squared test, with a Fisher's exact test for validation of results. Significance was determined at $p<0.05$. The population sample was coded into three climate regions (hot, warm, and mild) for comparative analyses.

Results: There were a number of findings with significant associations. In the hot and warm zones respondents were more likely to indicate that they have experienced extreme heat or heatwaves *often* (63.2% in hot zone and 66.7% in warm zone) in recent years, compared to sometimes. The hot zone also had the highest proportion of respondents reporting an *increase* (32.4%) in heatwaves or extreme heat in recent years, followed by the mild zone (25%). The warm zone had the highest proportion of respondents observing a *change* (17.1%). Respondents in the hot zone were also more likely to agree that their own actions can reduce the risk that heatwaves present to them and their families (83.8% *strongly agree* or *agree)*, and were also more likely to agree with a statement that there will be serious health consequences in their community due to heatwaves in the future (86.5% *strongly agree* or *agree*).

Recall of health warnings during heat events in recent years was high across all climate regions (average 89.3%). Of those householders that did recall warnings, the majority did take the warnings *very seriously* or *seriously*. A small proportion in the warm and mild zones did not take the warnings seriously at all (13.8% and 5% respectively). Those in

the mild zone were least likely to change their behaviour as a result of the warnings, with 28.6% reporting no change in behaviour.

Discussion: The study findings suggest that populations in cooler zones may be underestimating their risk of negative health outcomes due to heatwaves. This is of concern as heatwaves are expected to increase in frequency and magnitude with the increasingly discernible effects of climate change. Householders in the hot zone tend to be more aware of the dangers and risks posed by heatwaves, and were more likely to change their behaviours and take warnings seriously. Despite higher levels of exposure to extreme heat, they have adapted their behaviours and attitudes to protect themselves.

There was a high level of heat warning recall across all climate regions, with a general consensus that the warnings were appropriate. This indicates that warnings are being disseminated through appropriate channels, however a small proportion of the population may be at greater risk if these messages are not being delivered.

This study was limited by the small sample size, with some variation in age and sex population profiles across the three climate zones. There is also the possibility of other confounding factors or mediators, such as socio-economic status, affecting the results.

Conclusion: It is important to examine attitudes and responses to heat warnings in regional and rural populations because the interventions and policies developed for urban settings will not always be appropriate in other contexts. Policies and interventions need to be tailored for these communities in order to better communicate messages for better health and resilience. Climate also needs to play a role in the development of interventions, as it is clear that in some climate regions the attitudes of some community member's may be placing themselves and their families at risk due to their underestimation of the dangers of extreme heat or heatwaves. There is a need for further research into regional and remote populations on a national level, with a focus on the role of climate on adaptation, attitudes, and responses.

Table of Contents

Tables

Figures

1.0 Introduction

One of the most dangerous natural hazards for population health in Australia is extreme heat, particularly for vulnerable groups. Excessive and prolonged exposure to heat can cause heat stroke, heat exhaustion, heat syncope, heat cramps, and exacerbate a number of medical conditions (1). Heatwaves are of a particular danger. During an extreme heat wave, mortality can rise significantly, and ambulance call-outs can increase. During a 2009 heatwave, mortality increased by 62% in Melbourne and 10% in Adelaide (2). Extreme heat events are projected to increase in the future, which can be attributed the ongoing and escalating effects of global warming (3).

A heatwave generally refers to an episode of extremely hot temperatures (4), although the exact temperature that needs to be reached and for how long depends on the location. A problem that needs to be addressed in regards to heatwaves is how the health risks are perceived, especially when warning systems are in place, and how locality and climate may influence public perceptions, protective behaviours and health outcomes. The way that the population perceives and reacts to heatwaves and heatwave warnings is essential in protecting their health. If the public and vulnerable groups do not feel that heatwaves are dangerous, and do not believe or are not aware of the severity of negative health outcomes, they may place themselves at increased risk and become more susceptible to negative consequences. Understanding how populations in diverse regional areas understand and perceive their risk is vital in understanding where public health action and policy must be aimed.

In 2015, a household telephone survey (n=499) was conducted to examine perceptions of householders to heat and heat warnings in regional South Australia and Victoria (5). The availability of this existing survey data provided an opportunity to examine how public perceptions of heatwaves and heatwave warnings influenced by location and climate in regional areas of South Australia. The aim of this research is to compare the responses of participants across the main climate zones that are present across South Australia using existing survey data. The research question that is the focus of this research is "*How are public perceptions of heatwaves and heatwave warnings influenced by climate zone in regional areas of South Australia?*"

2.0 Literature Review

The objective of this literature review is to identify what is already known about the impact of extreme heat on populations across varying geographical locations, and to find where there are gaps in knowledge and evidence. Specifically, there was a focus on finding multi-location comparisons that included spatial, geographic, and climate aspects. Furthermore, there was some searching into heatwave warning systems and perceptions, in order to see how studies have been conducted and whether the results are meaningful in terms of statistical significance and in relation to real world policy and action recommendations.

Literature was identified through a variety of methods. The main method was searching the PubMed and SCOPUS databases using a structured search strategy in the form of logic grids. The grids contained several key words and their variations including 'heat', 'heatwave', 'perception', 'climate', and 'warning system'.

Some further articles were recommended by experts in the field. These were especially important as several of the publications did not appear as results in the database searches despite having a high level of relevance

Finally, a very small number of articles were identified through forward and backward searching. This method only yielded an additional two relevant articles. Many of the articles identified during forward and backward searching were already present in search results or had been recommended. Forward and backward searching was the least effective method, and supplied only two key articles (6, 7).

Seventeen key articles were selected for evaluation and appraisal. The articles cover a variety of topics with various study designs and methods utilised for each one. Evaluation and appraisal was done based on strengths and weaknesses, especially in regards to the relevancy of the paper to the topic. Analysis of strengths and weaknesses additionally took into account the study design, the logical progression of discussion and conclusion, the reliability and accuracy of the results, and the limitations of the data and study designs.

2.1 Who is vulnerable?

Of primary importance to public health is to examine who is most vulnerable to heat. Two key articles have been identified in relation to this, the first one focusing on Heat Vulnerability Indices (6), and the second one looking more at the variables studies often use when researching heat vulnerability, impacts, and thresholds (7). The first study (6) is a review of fifteen articles, and compares the determinant of heat vulnerability in each study, and how they have been weighted when constructing the index. The main determinants which increase vulnerability, and have a medium-high level of agreement across studies include the magnitude of the hazard (i.e. temperature), age, population density, timing of the heat event, pre-existing medical conditions, poverty (i.e. lack of income) and deprivation (i.e. the effects resulting from lack of income) (6). In comparison, the study by Hajat and Kosatky (7) which looked at seven different studies, recognised main contributing factors to heat mortality as being age (in particular in regards to ageing populations), population density, the Urban Heat Island (UHI) effect, and heat thresholds (an indication of the level of heat adaption/tolerability in a population). Cities with a lower Gross Domestic Product (GDP) were also noted as being more vulnerable, and the discussion moved to inferring that the higher vulnerability is due to lack of air-conditioning (7). Air conditioning is often used to mitigate the effects of heat and keep cool, and in many places is the main method of keeping cool. Without air conditioning other, perhaps less effective, strategies must be employed.

2.2 Comparisons between cities

Comparisons of temperature mortality relationships across cities are some of the more common studies available in regards to heatwaves, and can offer a great deal of insight into the role of various risk factors. A 2002 study by Currierio et al. (8) compared eleven cities on the eastern coast of the USA and concluded that temperature related mortality was concentrated in the most in the elderly and frail. The study investigated both heat and cold deaths, and found that those adapted to cooler climates were more vulnerable to heat events, and those adapted to hotter climates were more vulnerable to cold events. However, there was no extensive discussion about how climate across the cities varied, and the authors noted that seasonal migration of populations could be a significant confounding factor.

However, two studies have done city comparisons and discussed the role of climate in their results. Carmona et al. (9) compared mortality across a number of cities in Spain, looking at the impact of both heat and cold events. Results indicated the impact of cold events to be more significant than that of heat events. The study was more heavily focused on the effects of cold, and noted that populations in mild climates had higher mortality caused by cold than those already living in cool climates (9). A more in-depth discussion on climate was found in a Chinese study comparing four cities, each in different climate zone (10). Heat thresholds in each city were different because of their climates, and subtropical and temperate locations were the hottest with the highest thresholds. Factors like air-pollution were controlled for; especially since each of the four locations were large urban cities. However, despite climate being a part of this study, there was no extensive discussion on its role.

2.3 Comparisons between urban and rural locations

Other comparisons and studies that have been undertaken include investigating differences between rural and urban locations. The UHI effect is often discussed in studies, so contrasting with regional and rural locations is key to understanding the effect more deeply. One main study from Germany is a comparison between the city Berlin and the state Brandenburg that surrounds it (11). Brandenburg being a larger area than Berlin has more locations that are rural and is not as highly urbanised. The seventeen-year time-series analysis found that both urban and rural regions saw an increase in mortality during identified heat stress periods, however Berlin had the largest increases in mortality, which the authors attribute to the UHI effect (11). However, a study looking at rural population centres in Victoria, Australia, stresses the importance of setting heat thresholds for rural locations (12). Even if these populations are not as vulnerable due to the lack of the UHI effect, other factors such as the age of the population, the climate, and the socio-economic status can still put these populations at significant risk (12).

Identifying the differences in temperature related mortality between urban and rural regions has been the focus of only a small number of studies, and results can be conflicting. A time-series analysis of temperature mortality in England and Wales found that the population over the age of 65, in particular women, were most vulnerable to heat and cold events (13). Residents in London were at elevated risk compared to rural areas, although it was quite clear that some rural areas were at significantly higher risk than

others were, indicating a potential associated with deprivation. However, there is also a problem of data from rural areas often being less reliable and having a higher margin of error. Despite this, there was good control for confounders, and the study illustrates that the urban/rural dichotomy is not a deciding factor for risk. In fact, a study of rural and urban locations in British Columbia, Canada, reported an overall higher relative impact of heat in regional areas compared to urban ones (14). Furthermore, the study reinforced that climate and adaptation have a role in determining risk, as populations from cooler climates showed the highest susceptibly to heat. There was however, a lack of control for some key confounders such as socio-economic status and other demographics (14).

A study between urban and rural locations in Bangladesh noted a number of differences between urbanised and less well-developed areas (15). During extreme heat events when temperatures reached above the threshold levels, heat effects in urban areas had a much longer lag period (time in which heat effects continue to manifest), up to three weeks compared to one week in rural areas. Other findings in the study were much more limited due to a small number of observations above the temperature thresholds, thus giving data a higher margin of error and increasing the difficulty of interpretation (15).

2.4 Advantages of spatial mapping and analysis

Spatial mapping and analysis can be a powerful tool for research and for policy. Modelling health risks in cities and locations spatially can be difficult, but the models can be highly predictive and identify areas of higher risk, and can assist in the decision making process of governments (16). The main issue with this method, however, is that appropriate and reliable data must be available.

Vaneckova et al. (17) analysed the geographical patterns of heat-related mortality in the elderly population across Sydney between 1993 and 2004. A spatial regression and cluster analyses identified which areas had significant increases in mortality on extremely hot days. Furthermore, this modelling included variables such as socio-economic status, vegetation, and developed land (17). However, this mapping was of an urban area, but it is clear that this type of analysis can be done on a variety of levels assuming appropriate data is available.

At least three other studies were identified that spatially analysed entire states in the USA. One looked at Ohio (18), another at North Carolina (19), and the last at Massachusetts (20). The study on heat mortality across Ohio is a study which tends to conflict with other literature, due to the fact that the authors concluded that urban areas are not more at risk or more vulnerable to heat than rural ones (18). There can occasionally be an issue with spatial analysis when there is a lack of reliable measurements and when interpolations or estimations have to be made.

The study of North Carolina is one of the few looking at morbidity as opposed to mortality, and like the Ohio study, found that those in rural areas saw greater hospital admissions compared to those in urban areas (19). Furthermore, both the North Carolina and Massachusetts studies bring to light that the factors that influence mortality and morbidity in urban areas are different to those in rural areas (19, 20). Vulnerability is made up of both risk factors and protective factors which are different across urban and rural areas, but may also be further affected by culture and climate.

2.5 Perceptions and heat warning systems

One the key elements of the research question is based on perceptions of heatwaves and heatwave warning systems. Some research on this topic has been done, but more attention needs to be given to this aspect in the future. Kalkstein and Sheridan (21) assessed the response of the public in regards to heat health warning systems in Phoenix, Arizona, USA. The main contributing factors determining behaviours and responses to heat warnings were demographics and risk perception. Demographic characteristics also played heavily into risk perception, with women and those identifying as Hispanic having higher risk perception compared to other demographic groups. One very important effect that was observed was titled the "cry wolf" effect, which is when warnings are not taken seriously or disregarded because of no negative effects having occurred during past warnings (21). A wider study by Sheridan (22) on four different cities found similar results, and took special note that while a majority of people are aware of warning systems, where they are in place, there needs to be a focus on educating populations about how to respond to the warnings. This can be done by increasing by risk perception; the greater the perceived risk, the more likely people are to engage in personal mitigation strategies (21, 22). An issue that heat warning systems face is that many people feel the warning is not aimed or not applicable to them and that they are not vulnerable (22).

Reasons that people may not act on heat warnings is due is the idea that it is hot throughout summer anyway, or that they change their behaviours during summer overall rather than only in response to a warning or advisory. Other reasons for disregarding warnings included those who felt the warnings were irrelevant because they were working indoors or outdoors and the warning would not modify their working environment (so what can they do about it?), or that they are not worried because warnings are issued all of the time (21). Additonaly, there are also some people who do not have the capacity or resources to take precautions. For example, the may not be able to afford air conditioning, or may not be located close to a public air-conditioned location, assuming they have transport capacity in the first place.

2.6 Gap Analysis

There are definite gaps in the literature, and within this literature review. One area that has not been covered in this review is in regards to work safety and those who work outdoors and may be affected by heat, but these articles were excluded, as outdoor work is not a focus in this particular study. It is unclear whether all outdoor workers are vulnerable, as they often have to follow particular health and safety regulations. Although there is extensive literature on outdoor workers and heat, this is beyond the scope of this project, and would be better suited as a separate more narrowly focused project around work safety and heat specifically. Furthermore, the data that is available for analysis does not focus on work habits in-depth, although data about work status and exposure to heat through outdoor work were two questions that were asked of participants. However, two questions alone do not provide a detailed picture of the situation.

Overall, while this review has highlighted a number of articles about the impact of high temperatures in rural areas, it is still an area that is underrepresented, with poorer data compared to studies focused on urban locations. The role of other climate characteristics is also rarely discussed, with many papers focusing on heat thresholds and maximum temperatures, with less concern about the wider types of climatic zones and how they affect physiology and population health trends.

Most of the articles had different study designs, with various methods and sources of data, and tended to explore only a few specific variables, or alternatively a large number of variables but with a more difficult analysis. Due to the complexity of vulnerability and all of its protective and risk factors, there are a number of confounding factors in each study,

some more obvious than others; while correlation can be established, causation is much harder to measure.

Furthermore, many articles use mortality to measure or validate vulnerability and risk. However, in comparison there are fewer studies incorporating morbidity, which is also a vital aspect and may be a more sensitive indicator. It could be possible that highly vulnerable locations are not being recognised when the focus has only been mortality, when some of those risk factors can be causing high levels of morbidity but not necessarily resulting in fatalities (i.e. increased hospitalisations and paramedic dispatch requests). Morbidity is not of lesser importance than mortality when looking at the health and vulnerabilities of populations.

When it comes to risk perception and responses to heatwave warning systems, there are also gaps in terms of the amount and quality of the literature. While two excellent examples were chosen for this review, it would have been more advantageous and relevant if Australian based articles of similar nature were also available. Overall, Australian based research makes up only a small amount of the research in the field, which is mostly from North America or Asia. However, Australian literature is the most relevant to this study, so it makes a vital part of the literature review and acknowledges the varied and unique climates across the country.

Another issue in regards to studies around temperature mortality and morbidity is that the outcomes are likely under-reported, obscuring the extent of the problem. Not all deaths or illnesses are necessarily coded properly for identification as being related to heat (or cold), and people who suffer effects from heat may not always present to emergency or to a doctor with their problem, or they may present some time after the actual exposure.

The rural and urban dichotomy can also be problematic, as these definitions can vary depending on how they are being measured. Population density or land development are two types of measurements that can be used, either individually or as a combined index. Furthermore, there is diversity between and within different rural and urban settings. Urban and rural areas also vary widely between countries. In some nations a rural area could be considered a very poor place with limited power and water, in other countries a rural area may just be a less developed town away from large urbans hubs or mega-cities.

A final gap that has been identified, and which has been mentioned several times, is the complexity of vulnerability. There is a definite need for better understanding vulnerability, and while this research does not specifically address vulnerability, it does look at the geographic distribution of elements that contribute toward vulnerability and resilience.

3.0 Methods

This project involves analysis of data from a household survey (*n*=499), conducted in non-metropolitan South Australia and Victoria, to examine public responses to extreme heat and heat warnings. The data was examined with a focus on identifying any geographic or regional patterns in the responses. The analysis focused on looking at the data spatially and assessing the impact of the findings on shaping public health action and policy in relations to regional heat warning and climate change adaptation. Only data from South Australia (*n*=251) was used in this instance. The survey was developed in the School of Public Health and conducted by the Health Monitor Survey service provided by Population Research Outcome Studies (PROS), the University of Adelaide, in conjunction with Harrison Health Research. Surveys were conducted using a Computer Assisted Telephone Interview (CATI) format, and were delivered between 28/04/2015 and 18/05/2015.

There are no issues with ethical concerns, as the data does not contain personally identifiable information, and during collection did not cause any distress or harm toward participants. Collection of data was undertaken with the appropriate ethical clearance from the University of Adelaide Human Research Ethics Committee (Ethical approval H-2014-281).

The questionnaire had a number of questions that focused on behaviours and various perceptions about severity and susceptibility to heatwaves. Fourteen relevant questions were selected from the survey for analysis in this project. These questions were selected because they were deemed relevant to both climate and the research question in terms of exploring responses to heatwaves and heatwave warnings, in addition to perceptions of severity and susceptibility.

Analysis was conducted using IBM SPSS version 23. Data was first checked for any errors such as missing values or typographical errors, and SA data specifically selected for

analysis. Each Statistical Area at level 2 (SA2) was coded according to climate zone, based on the climate zones present in the National Construction Code (NCC) Guides (23)(see *Appendix A* and *Appendix B*). There were three climate zones defined within the state, which were based on collapsing the existing six climate zones as defined by the Bureau of Meteorology (BoM), and fitting into SA2 boundaries. Using the simplified zones fitted into the SA2 regions was more appropriate for this study, as we did not have data for exact location of the respondents, and trying to place within the more detailed zones would have been impossible.

Analysis was based on the three climate zones, with Zone 4 being defined by a hot summer and cool winter, Zone 5 as having warm temperature, and Zone 6 having only mild temperatures. The Zones are based off of the Köppen climate classifications (24).

A variable set was defined in SPSS with the relevant questions and associations between responses and climate zone were tested using a Chi Square analysis. A value of $p<0.05$ was used for significance. A major limitation to note was that the number of respondents in each climate zone was unequal, Zone 4 having the lowest at $n= 37$, Zone 5 with $n=81$, and Zone 6 being the most populated at $n=133$. Fisher's exact test was also conducted where possible to verify significance; this was done due to the small sample size and unequal distribution of the data (25).

Some response categories were re-coded or collapsed to reduce the impact of the small sample size. For example, some of the 10-point response scales were recoded into three categories, 1-3, 4-7, and 8-10, in order to assist in analysis, and 5-point scales from strongly disagree to strongly agree were also collapsed into three categories consisting of agree, disagree, and neutral/not sure. Notes on recoding are included in the results alongside the relevant questions.

3.1 Demographics of population sample

In *Figure 1,* the demographic profile of the overall sample population has been illustrated. All respondents were adults, with a relatively equal gender split for all age groups. Adults between the ages of 35 and 64 were the largest cohort, constituting approximately 53.8% of the sample. Young adults aged 18 to 34 were 23.5% of the sample, and older persons made up the remaining 22.7%.

Figure 1 Age and gender distribution of the overall sample population

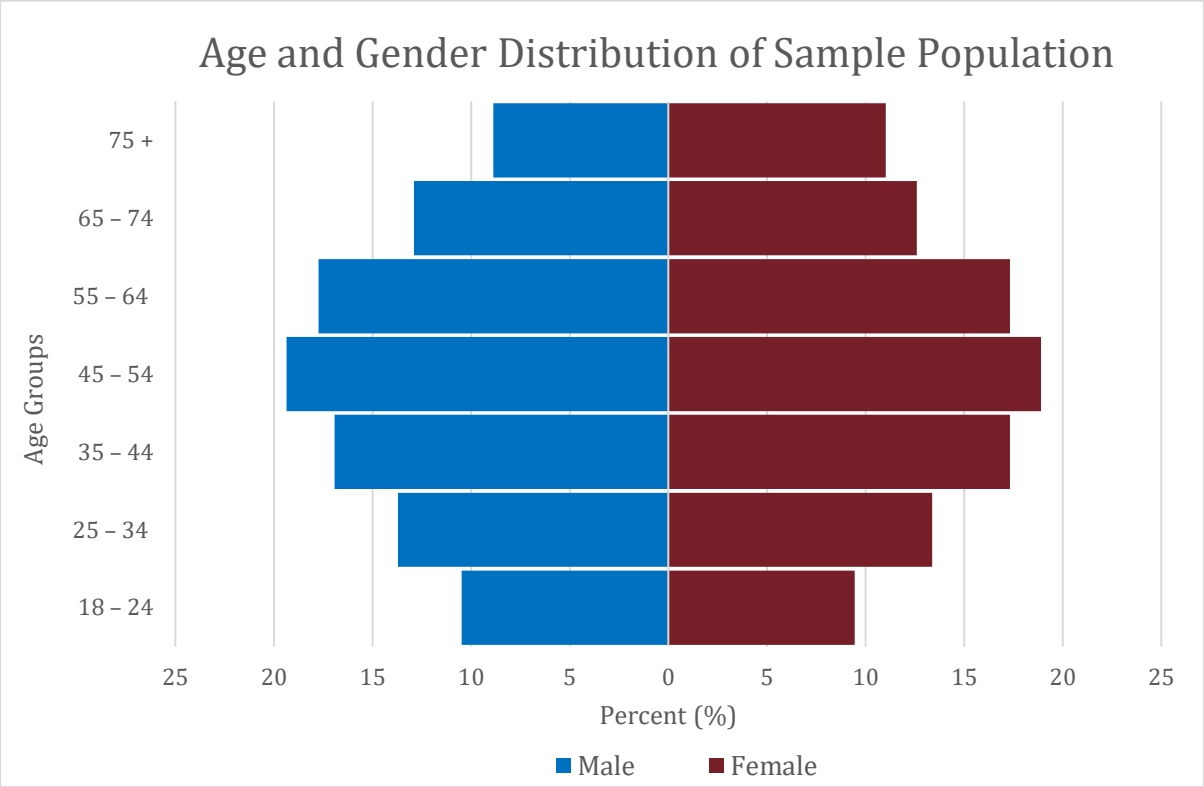


Figure 2 illustrates the age and gender distribution in the hottest zone. Due to the small sample size in this region, the distribution is variable. The gender split was even, however, with 19 male and 18 female respondents.

Figure 2 Age and gender distribution of sample population in Zone 4

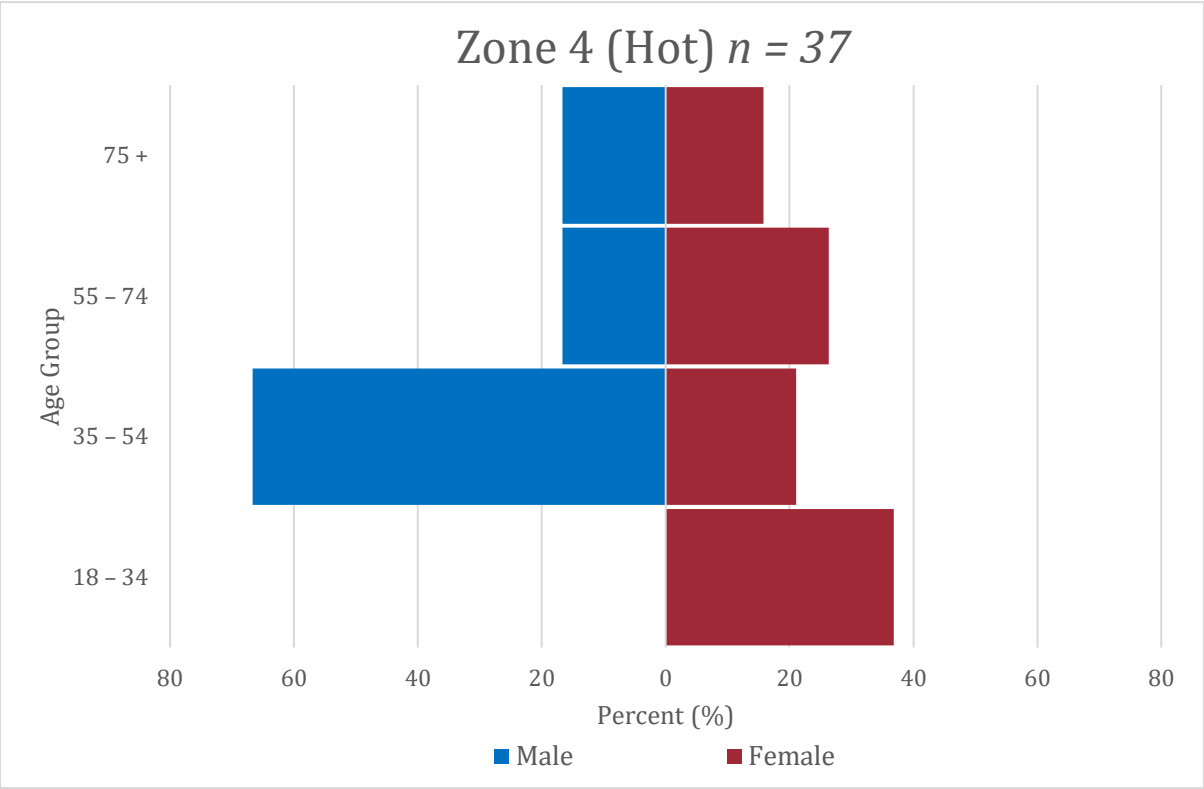
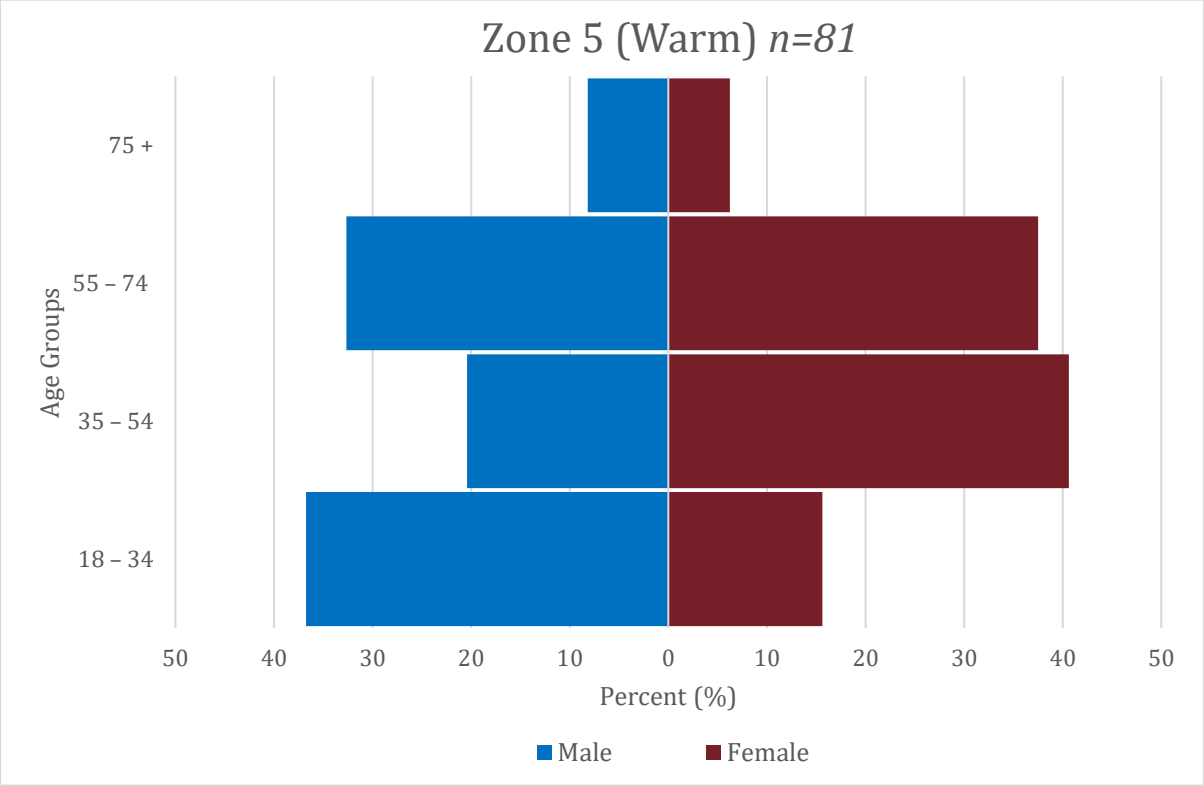


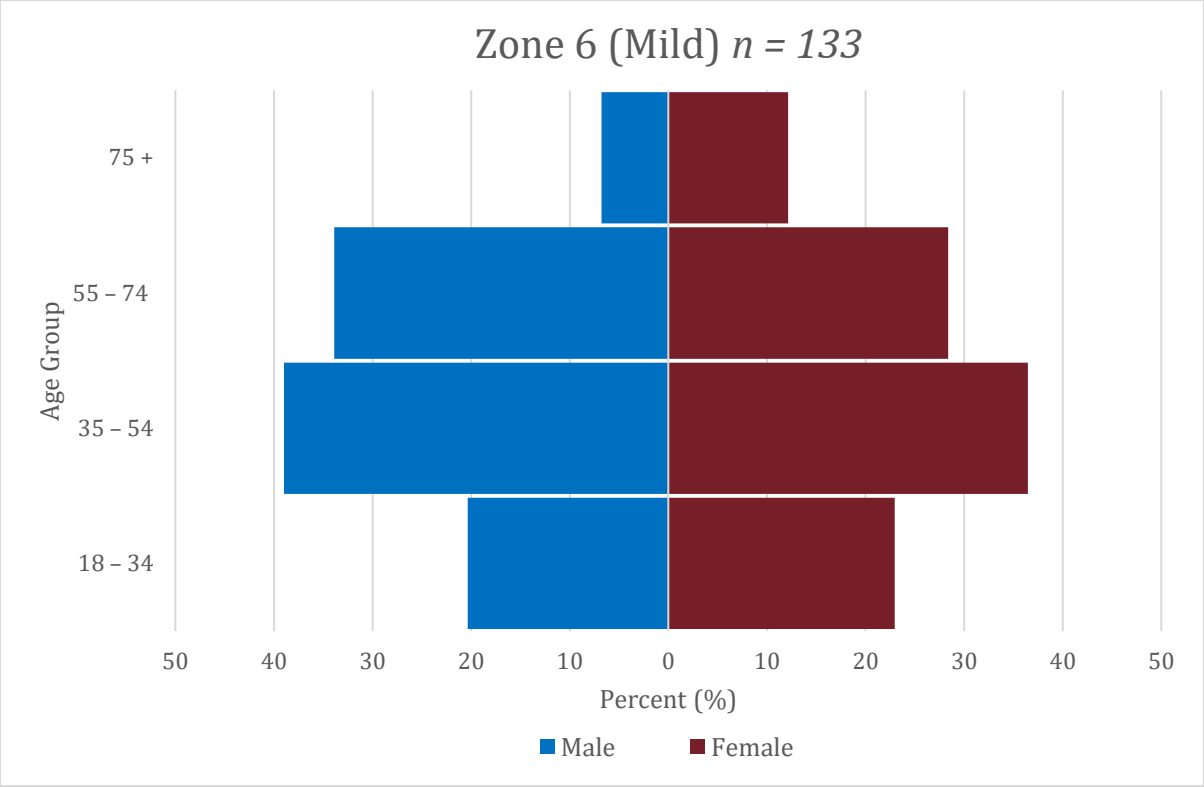
Figure 3 illustrated the age and gender distribution in Zone 5, the warm zone. A key factor to note about this population is that there were 49 male respondents, compared to only 32 female respondents. The uneven gender split is most prominent when looking at the youngest age group; adults aged 18 to 34, an age category that contained fewer female respondents and relatively high proportion of male respondents.

Figure 3 Age and gender distribution of sample population in Zone 5



Finally, *figure 4* illustrates the distribution in Zone 6, the coolest of the three zones, and which was the largest population sample. The gender split was skewed toward females in this case, with 59 male and 74 female respondents.

Figure 4 Age and gender distribution of sample population in Zone 6



4.0 Results

4.1 Perceptions and perceived coping ability

Respondents were asked about their experiences with extreme heat, and whether they experience extreme heat *often*, *sometimes*, or *not at all.* In *Table 1*, the results asking about heatwave experience are shown. Respondents who replied *'no'* were not interviewed further. A Pearson Chi-Square test indicated that there was an association between climate zone and the response to this question *(p = 0.006)*. In climate Zone 4 and 5 over half of respondents indicated experiencing heatwaves often, however, in the cooler Zone 6 less than half of respondents indicated experiencing heatwaves often.

Table 1 Have you experienced heatwaves or extreme heat in recent years?

CLIMATE ZONE	YES, OFTEN	YES, SOMETIMES
ZONE 4 (HOT SUMMER/COOL WINTER)	63.2%	36.8%
ZONE 5 (WARM)	66.7%	33.3%
ZONE 6 (MILD)	45.5%	54.5%
TOTAL	55%	45%

Respondents were asked to rate how well they feel they cope with extreme heat on a scale of 1 to 10, where 1 means not at all well and 10 means very well. Overall, respondents tend to feel that they cope very well. The results shown in *Table 2* are based on the recoding of 'Not very well' represents rankings of 1 to 3, 'moderately well' represented rankings 4 through to 7, and very well represented responses 8 through to 10. There was no significant association between the distribution of responses and climate zone *(p>0.05)*.

Table 2 How well do you feel you cope with extreme heat during heatwaves?

CLIMATE ZONE	NOT VERY WELL	MODERATELY WELL	VERY WELL
ZONE 4 (H)	5.3%	26.3%	68.4%
ZONE 5 (W)	9.9%	28.4%	61.7%
ZONE 6 (M)	6.0%	32.3%	61.7%
TOTAL	7.1%	30.2%	62.7%

The results in *Table 3* suggest that climate zone may influence whether heatwaves affect respondents' health or well-being. In the analysis, when the 'maybe' responses were included there was a borderline significant association with climate zone ($p = 0.046$), however when the analysis excluded the 'maybe' category there was no longer a significant association. The exclusion of the maybe category was to test whether there would be significance detected when considering only the *yes/no* responses. Due to the small sample size, any supposition or inference must be made with great caution. What is clearer though, is that in the warmer Zone 4, over half the respondents felt that heatwaves affected their health, with a proportion uncertain, meanwhile in Zones 5 and 6 less than half felt they were affected.

Table 3 Do you feel that heatwaves affect your personal health or well-being at all?

CLIMATE ZONE	YES	NO	MAYBE
ZONE 4 (HOT)	55.3% *(60.0%)**	36.8% *(40.0%)**	7.9%
ZONE 5 (WARM)	35.8% *(36.7%)**	61.7% *(63.3%)**	2.5%
ZONE 6 (MILD)	44.7% *(45.4%)**	53.8% *(54.6%)**	1.5%
TOTAL	43.4% *(44.7%)**	53.8% *(55.3%)**	2.8%

* result after recode and removal of 'maybe' category

Respondents were asked to rate how well they could keep their homes cool, on a scale of 1-10, where 1 means *not at all well* and 10 means *very well*. The responses were recoded for analysis such that '*not very well*' represents rankings of 1 to 3, '*moderately well*' represented rankings 4 through to 7, and '*very well*' represented responses 8 through to 10. As illustrated in *Table 4,* the majority of respondents reported high scores, and there was no statistically significant association with climate zone. In the warmer zones (4 and 5), there were some respondents who ranked their capability as being quite poor, compared to the coolest zone where no respondents said that they coped poorly in this regard.

Table 4 How well can you keep your home comfortably cool during heatwaves?

CLIMATE ZONE	NOT VERY WELL	MODERATELY WELL	VERY WELL
ZONE 4 (H)	5.4%	18.9%	75.7%
ZONE 5 (W)	2.5%	30.0%	67.5%
ZONE 6 (M)	-	27.8%	72.2%
TOTAL	1.6%	27.2%	71.2%

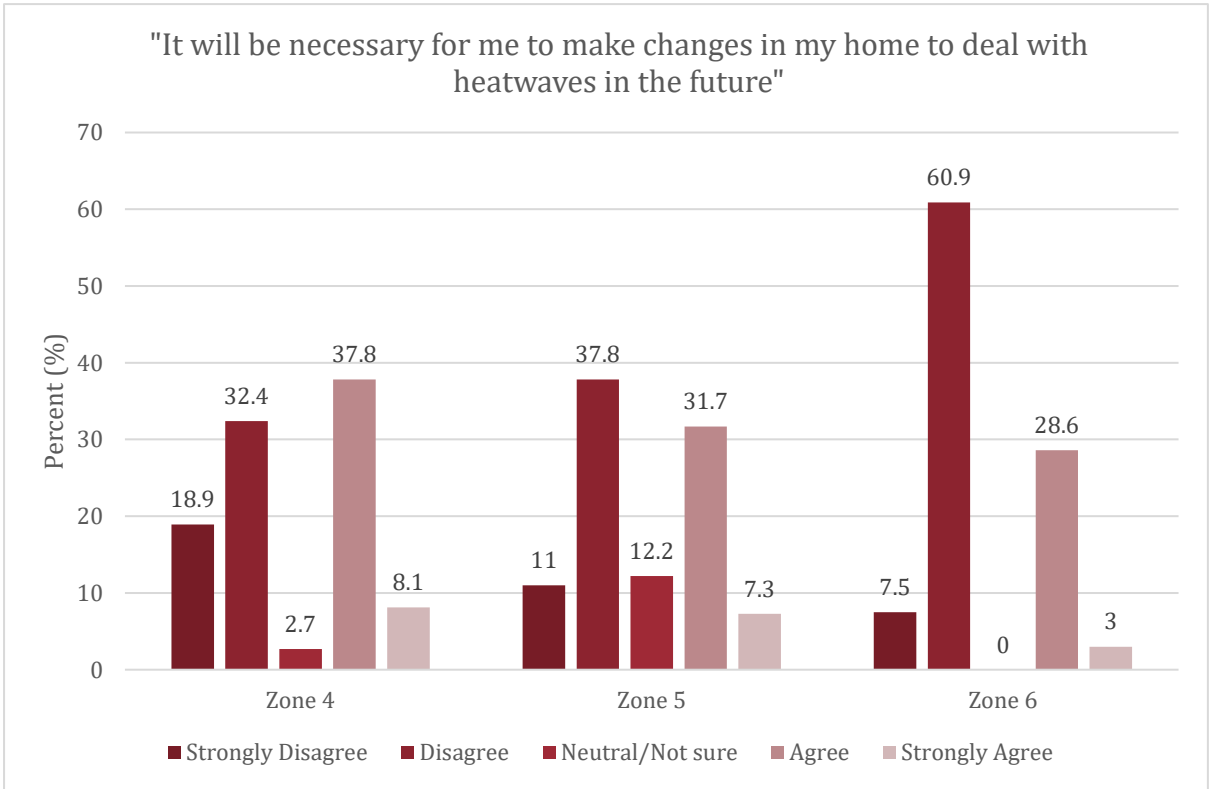
Table 5 presents the responses when respondents were asked about any changes in their experiences with heatwaves. Over half of respondents indicated observing a change or increase in heatwaves or extreme heat. While there was a significant association between the distribution of these responses and climate zone *(p = 0.019)*, when the data was recoded and analysed into *yes/no* format with '*not sure*' responses being classified as '*no*', the association was no longer statistically significant *(p = 0.644)*. Perceptions about changing heat appear to differ between climate zones. While some respondents in Zone 5 and 6 reported only a change in heat, the respondents from Zone 4 were more likely to report an increase or increase & change in heat.

Table 5 Compared to the past, have you observed any increase or change in heatwaves or extreme heat in your region?

CLIMATE ZONE	YES, INCREASE	YES, CHANGE	YES, BOTH	NO CHANGE	NOT SURE
ZONE 4 (H)	32.4%	2.7%	18.9%	45.9%	-
ZONE 5 (W)	13.4%	17.1%	15.9%	43.9%	9.8%
ZONE 6 (M)	25.0%	13.6%	6.8%	47.0%	7.6%
TOTAL	22.3%	13.1%	11.6%	45.8%	7.2%

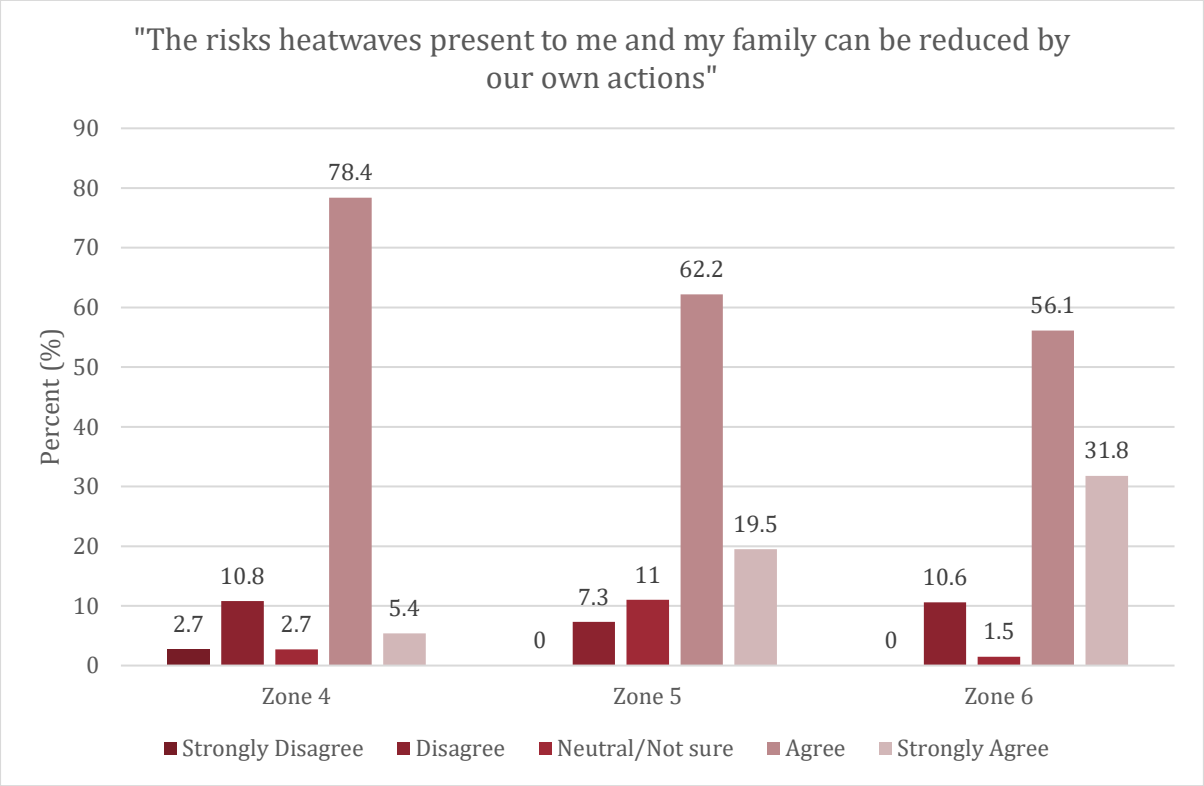
Respondents were asked to rate their level of agreement with the statement "It will be necessary to make changes in my home to deal with heatwaves in the future," and the distribution of responses are illustrated In *Figure 5.* The analysis indicated that the responses were significantly associated with climate zone *($p < 0.05$).* After collapsing the scale into agree, disagree, and neutral/not sure, the association with climate zone remained significant. What can be seen on the graph is that respondents in the warmer zones (4 and 5) are more likely to agree about needing to make changes compared to those in the coolest zone (zone 6). It should be noted, however, that there was also a relatively high level of undecided and neutral respondents in the zone 5.

Figure 5 Agreement with the statement "It will be necessary to make changes in my home to deal with heatwaves in the future"



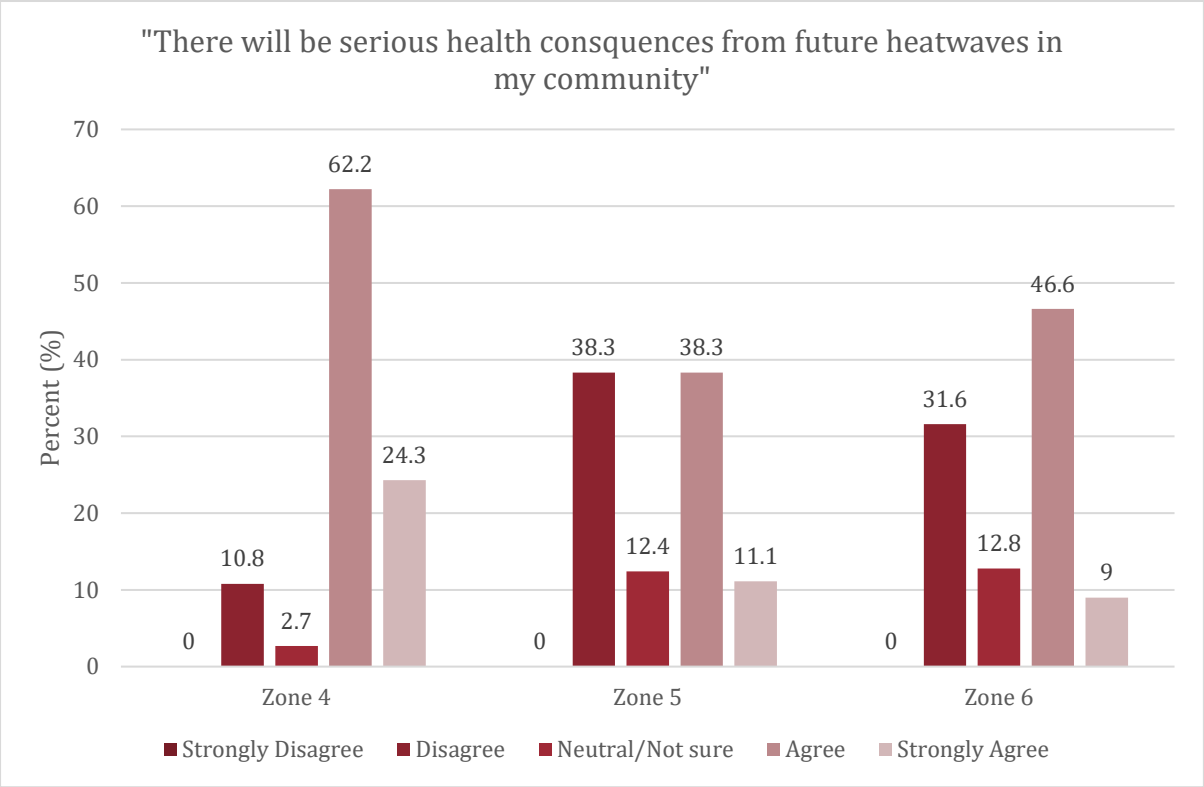
Respondents were asked to rate their agreement with the statement "The risks heatwaves present to me and my family can be reduced by our own actions," and the distribution of responses are illustrated In *Figure 6.* In each climate zone, most respondents agreed with this statement, with zone 6 having the highest overall agreement. Once again, there were a small number of respondents that were unsure and neutral. There was a significant association between the distribution of responses and climate zone *($p < 0.05$)*. After collapsing the scale into agree, disagree, and neutral/not sure, the association with climate zone remained significant.

Figure 6 Agreement with the statement "The risks heatwaves present to me and my family can be reduced by our own actions"



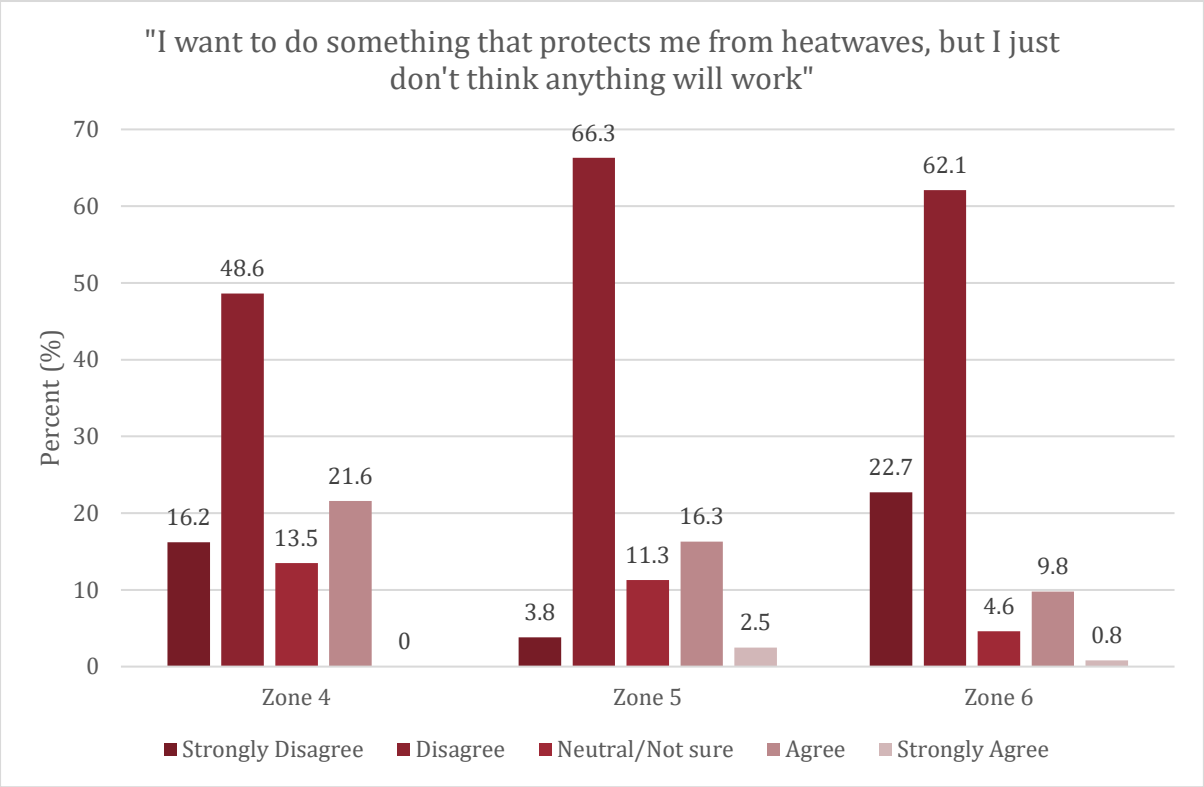
Respondents were asked to rate their agreement with the statement "There will be serious health consequences from future heatwaves in my community," and the distribution of responses is illustrated In *Figure 7.* The results illustrate that the most concern over health impacts is reported within the hotter climate zone (4), with the two cooler zones showing higher levels of 'disagree' or 'not sure' responses. There was a significant association between the distribution of responses and climate zone *($p < 0.05$)*. After collapsing the scale into agree, disagree, and neutral/not sure, the association with climate zone remained significant.

Figure 7 Agreement with the statement "There will be serious health consequences from future heatwaves in my community"



Respondents were asked to rate their agreement with the statement "I want to do something that protects me from heatwaves, I just don't think anything will work," and the distribution of responses is illustrated in *Figure 8.* Responses from Zone 6 respondents showed almost 85% disagreeing with the statement. Respondents from Zone 4 reported the highest level of agreement with the statement (21.6%). There was a significant association between the distribution of responses and climate zone *($p < 0.05$)*. After collapsing the scale into agree, disagree, and neutral/not sure, the association with climate zone remained significant.

Figure 8 Agreement with the statement "I want to do something that protects me from heatwaves, I just don't think anything will work"



4.2 Recall and perceptions of heat warnings

The survey included several questions designed to assess recall and perceptions of heat warnings in regional areas. *Table 6* illustrates the proportion of recall of health warnings within each climate zone.

Table 6 Responses to survey question "In recent years do you recall there being Health Warnings issued during extreme heatwaves?"

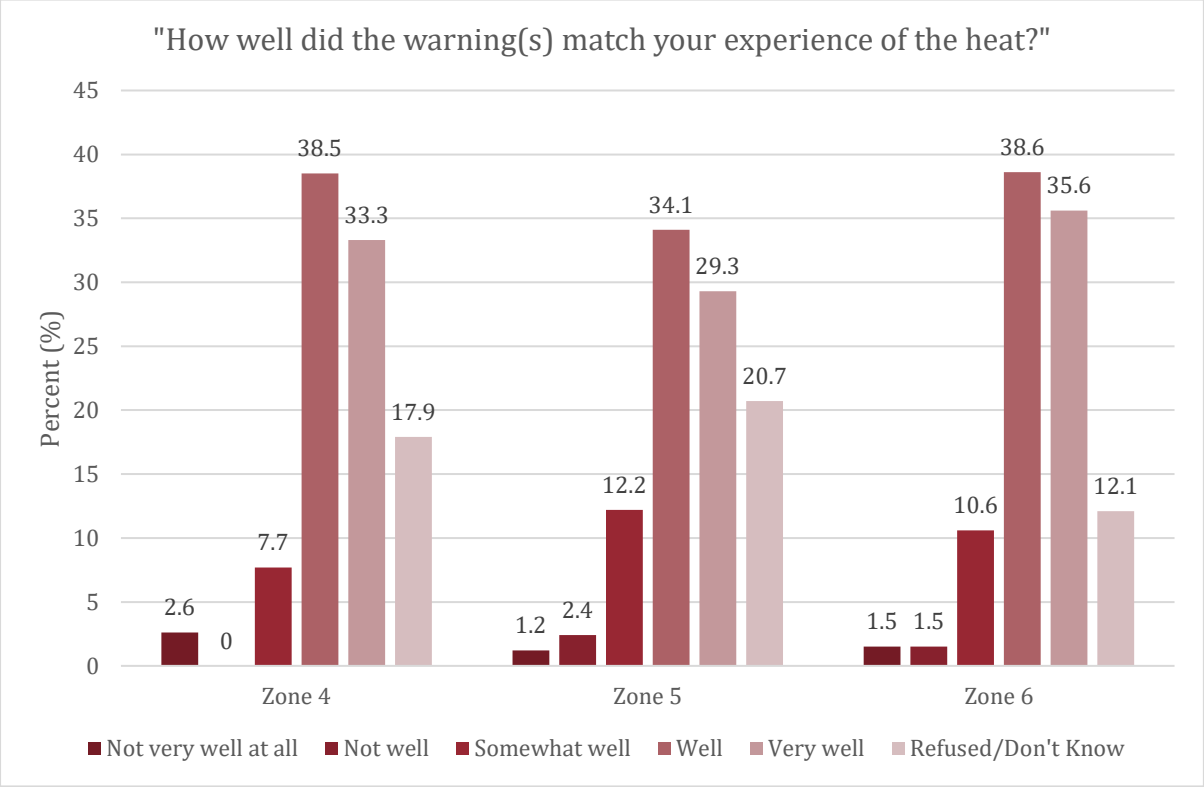
CLIMATE ZONE	YES	NO
ZONE 4 (H)	81.6%	18.4%
ZONE 5 (W)	89.2%	10.8%
ZONE 6 (M)	91.6%	8.4%
TOTAL	89.3%	10.7%

There was no significant association between recall of warnings and climate zone *(p=0.212)*, and it is clear that warning recall is excellent across all the regions.

For those that did recall heat warnings *(n=217)* there were several additional questions regarding those heat warnings. These questions were important to ask in order to gauge how effective the warnings were and how seriously they were taken by respondents.

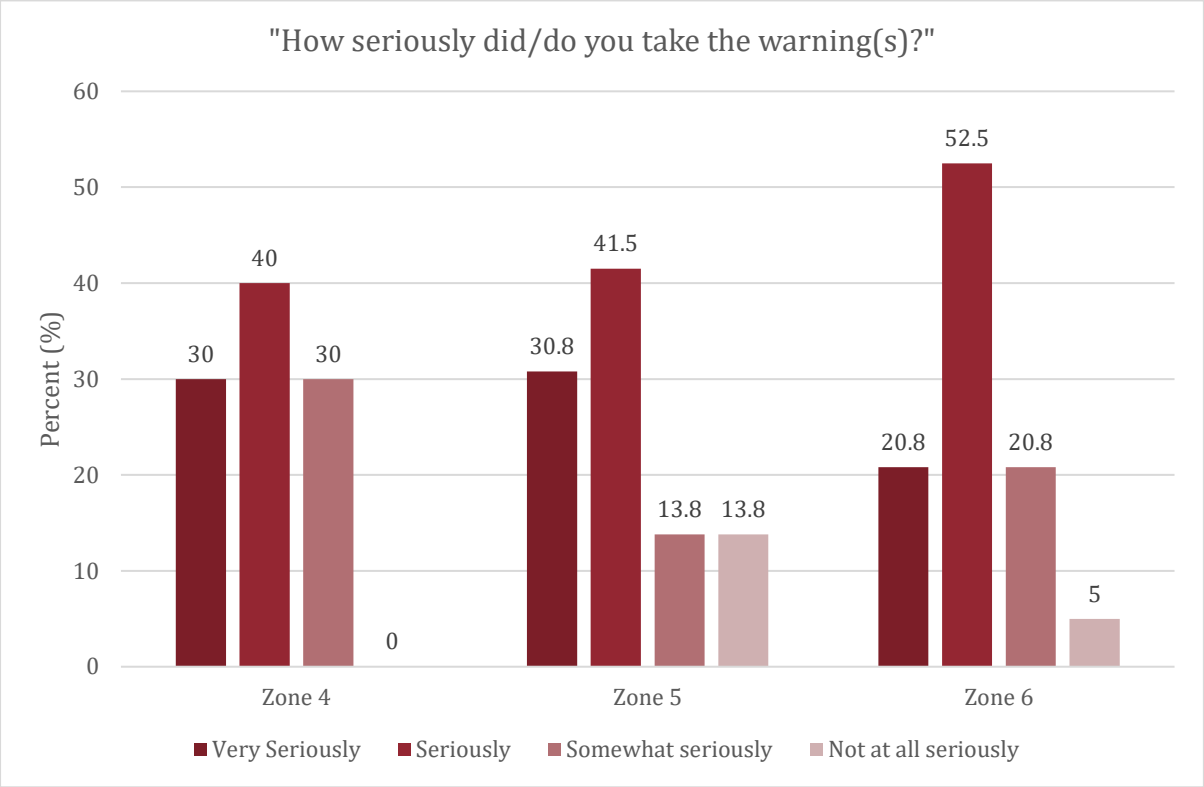
Figure 9 illustrates the distribution of responses to the question “how well did the warning(s) match your experience of the heatwaves?". Most respondents reported that the warnings matched the heat *well,* or *very well.* However, in all three zones there were a considerable number of people who could not recall if this was so. This is likely due to the time at which the survey was carried out, at the end of April and in early May. Recalling back to the heatwaves during the peak of summer may have been difficult for some people. Alternatively, there may have been an issue with the wording and interpretation of the question, confusing some respondents. Otherwise, it is encouraging to see that the warnings were deemed appropriate by many of these respondents. There was no significant association between the distribution of responses and climate zone.

Figure 9 Responses to statement "How well did the warning(s) match your experience of the heatwaves?"



Respondents were asked to rate how seriously they took the heat warnings, and the distribution of responses is illustrated in *Figure 10.* Across each zone, a majority of the respondents (>70%) reported that they did take warnings *seriously* or *very seriously*, with a small number of respondents in the Zones 5 and 6 not taking them at all seriously. After excluding the 3 respondents who were unsure, the analysis showed a significant association between responses and climate zone *(p=0.037)*.

Figure 10 Responses to statement "How seriously did you take the warnings?"



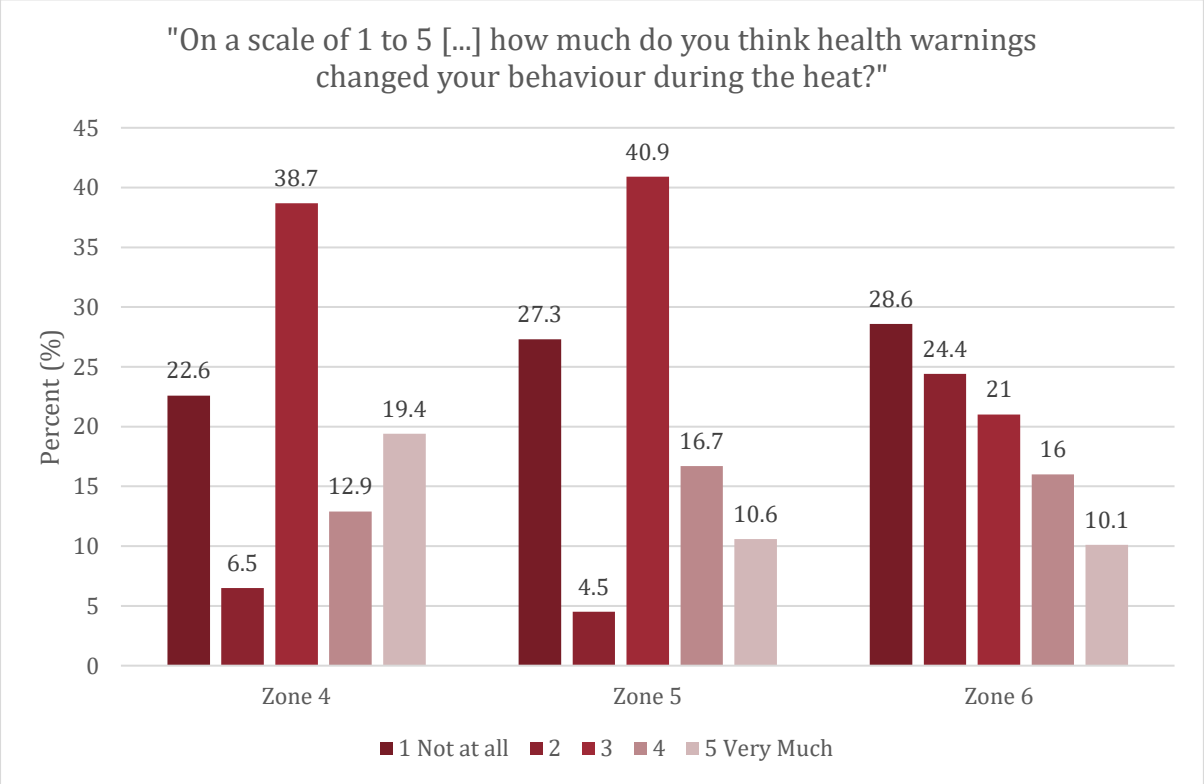
Respondents were asked whether they could recall any of the messages about how to maintain good health in the heat, and the responses are summarised in *Table 7.* This was important to ask as respondents may have recalled hearing heat warning messages, but not necessarily recalled the content and information within the warning. The results reflect the positive impact of the warnings, with a majority recalling the health messages. These messages are important in giving the respondents the information they need in order to engage in protective behaviours. There was no association between recall of health warnings and climate zone *(p=0.111)*.

Table 7 Do you recall any messages about how to maintain good health in the heat?

CIMATE ZONE	YES	NO
ZONE 4	90.3%	9.7%
ZONE 5	95.4%	4.6%
ZONE 6	85.3%	14.7%
TOTAL	89.2%	10.8%

Respondents were asked to rate, on a scale of 1 to 5, how much heat warnings had changed their behaviour during the heat, and the distribution of responses is illustrated in *Figure 11.* Reponses from Zone 6 showed these respondents were least likely to change behaviours in response to heat warnings. In Zones 4 and 5 there was a similar pattern of responses, with most respondents reporting *no change* (i.e. reporting a value of 1) or a moderate change (i.e. reporting a value of 3) in behaviour in response to warnings. The analysis revealed a significant association between distribution of responses and climate zone *(p=0.006).*

Figure 11 Response to question "On a scale of 1 to 5 how much do you think heat warnings changed your behaviour during the heat?"



5.0 Discussion

5.1 Experiences and Perceptions of heatwaves and coping ability

From the overall results, it is clear that climate zone does have an effect on householders attitudes relating to heat vulnerability and risks. Certainly, climate does seem to influence some experiences and behaviours, while others are unaffected. The discussion will be focused on investigating the links within the results and between the questions asked.

One of the main differences between the climate zones was that in the cooler zones householders were more likely to report experiencing heatwaves *sometimes*, as opposed to *often*. This link between climate zone and experience was to be expected, as those in warmer zones (4 and 5) would naturally be more inclined to receive more frequent exposure. On the other hand, while householders in zone 4 reported high levels of exposure, they also generally reported slightly better coping ability. While coping ability in itself did not have a significant association with climate, when linked back to the results of experiences of heatwaves, it is possible to speculate that perhaps in zone 4 there was a slightly higher level of adaptation. In comparison, the relatively cooler zones (5 and 6), had a higher proportion of respondents who rated their ability to cope with heatwaves on the low to mid-range of the scale (i.e. *not very well* and *moderately well*). In a study with more participants and with a more equal distribution of respondents across climate zones (and perhaps the inclusion of colder climate zones such as those in Victoria), the results of a question such as perceived coping ability may have had a significant association. While there is a link between climate adaption and susceptibility to heat or cold events (8, 9), in the case of this research the association was not detected either due to the limited sample, or the fact that coping ability is linked to multiple factors that may be unrelated to climate.

Most respondents reported high scores for ability to keep the home cool – a vital part of coping ability, and there was no significant association with climate zone. The lack of association with climate zone is probably attributable to the proliferation of air-conditioning in Australia. The proliferation of air conditioning in South Australia is difficult to estimate, but research suggests that up to 95% of homes in South Australia have air-conditioning (26). However, in regional areas this may be less compared to urban areas, and more-so in households with low incomes who can not afford a unit or limit their use due to financial concerns. Furthermore, in locations where power

infrastructure is poor, use can be limited due to brownouts or blackouts. It is possible that those who reported poorer ability to keep their home cool may have issues with air-conditioning. Other factors may also include the building materials of their home, the configuration and placement of the residence, and perhaps lack of knowledge or ability to employ alternate strategies. The question also required some interpretation from the respondent in regards to what keeping the home "cool" exactly means. Each household and individual's interpretation of keeping cool would vary depending on their preferences and overall capability. Adaptation may play a role in this type of question, as those from cooler climates may be more sensitive to increases in temperature and find it more difficult to reduce the temperature of the home to a level that is comfortable for them.

In regards to how respondents felt their well-being and health was affected by extreme heat, respondents in the cooler zones, 5 and 6, were more likely to say that they did not feel that their health or wellbeing was affected by heat. The reasons for this are not clear. It may be due to generally good coping ability, or they feel that the heatwaves they experience occur less often or with less intensity. It may also simply be an issue of not having any major experiences wherein the heat caused a negative outcome. Additionally, the respondents who answered *maybe* are an important sub-population to consider. Was their answer influenced by confusion in regards to question, or perhaps poor recall of the summer? There may have been some people who were genuinely unsure about the effect that heat may have on their well-being and health. This would indicate confusion about the exact effects heats may have on the body. If respondents did experience some negative health events during a heatwave, they may have been unsure as to whether those were caused by the heat or if they were caused by some other factor.

When looking at whether respondents have perceived any changes in heatwaves in previous years, almost half reported seeing a change or an increase in heatwaves. The meaning of *change* and *increase* may have included some interpretation from the respondents. *Change* would likely refer to aspects such as when heatwaves occur, how long they last, and the intensity (i.e. maximum temperatures) of the heatwaves. Increase would likely refer to the frequency of heatwaves, but perhaps also intensity in some cases. There were some respondents who were unsure whether there were any changes. This is probably simply due to a lack of recall and those respondents simply not taking notice

of changing patterns. It is not surprising that a majority did indicate that they are aware of the changing nature of heatwaves; due to climate change, the frequency, intensity, and length of extreme heat events (and other climate events) is expected to increase (27).

The survey included a series of items to assess householders' perceptions about future risks associated with heatwaves and their capacity to cope. Householders were asked about whether they would need to make changes in their home to deal with heatwaves in the future. Those in the warmer zones, 4 and 5, were more likely to report needing to make changes to their home compared to zone 6. This could be interpreted as an increased awareness of the challenges of future heatwaves in warmer regions. Alternatively, householders in the cooler zone 6 may feel their homes are already well-prepared for heatwaves, however this seems less likely. In order to deal with the changing nature of heatwaves in the future, some people may need to make changes in their home. The question that householders responded to did not specify exactly what types of changes would need to be made and in what regard – physical changes to the house construction, changes in some activities, installation or improvement of air-conditioning just to name a few. This could be a point for further research in regional areas. Zones 4 and 5 were more likely to report needing to make changes to home compared to zone 6. However, respondents in zone 5 were most likely to be neutral or unsure in regards to this statement. Unsure and neutral responses indicated either a problem with interpreting the question, a lack of knowledge about strategies to improve the home, or genuine uncertainty about whether modifications are required to cope with future heatwaves. Those who answered that they disagree with the necessity of making changes most probably felt that they already prepared for the future or have already done all they can do to their home to cope with heatwaves.

To assess householder perceptions of self-efficacy in relation to heatwaves, they were asked whether their own actions could reduce the risk heatwaves pose to themselves and their family. In general, there was agreeance across all the zones, over 80% replying either *agree* or *strongly agree*. Zone 4 was the only zone where a very small percentage of householders (2.7%) said they disagreed strongly with this statement. For those who did disagree or said they were neutral or unsure, perhaps there is a lack knowledge about the types of behaviour changes that can reduce risk, or those respondents are pessimistic or unsure about the effectiveness of some strategies. While the majority in the zone 4 did

agree with the statement, there were higher levels of people in strong agreeance in zones 5 and 6. Those respondents were likely more confident that their personal actions can have an impact on risk, possibly because their exposure to heat is lower, or alternatively, they have a higher level of knowledge about personal strategies to reduced risk, or they have the resources needed to take preventative actions.

Householders were further asked whether they agreed that there would be serious health consequences from future heatwaves in their community. Zone 4, the hottest zone, had the highest levels of agreeance from respondents. This is possibly due to their reported experiences of having heatwaves more often, and therefore perhaps having more exposure and knowledge about the dangers that heatwaves can pose towards particular populations (the elderly, those who are isolated or in remote locations, have poor housing, etc.). Zones 5 and 6, which are generally cooler, had higher levels of disagreement and neutrality/uncertainty in comparison with zone 4. This may be attributed to potentially lower knowledge and experience with the impacts of heat on health and well-being.

For the final item to assed perceived self-efficacy, householders were asked to rate their agreement with the statement *"I want to do something that protects me from heatwaves, I just don't think anything will work"*. Overall, the majority of householders disagreed with this statement. However, there was some agreement among respondents from zone 4 (21.6%), which was higher than in zones 5 (18.8%) and 6 (10.6%). These results generally affirm the results from a previous item about personal actions reducing risk of negative impact due to heatwaves. However, the phrasing of the questions was intentionally reversed from a positive phrasing to a negative one. There were some neutral/unsure responses in all zones, the most being zone 4 and then zone 5 (13.5% and 11.3% respectively). These responses may be reflecting a lack of knowledge and genuine uncertainty about the future and strategies for risk mitigation.

5.2 Discussion of recall and perceptions of heat warnings

There was a high level of recall of heat warnings across the climate zones, with approximately 89% of householders recalling warnings in recent years. This indicates a good level of dissemination of warnings within the community. The small number of respondents who did not recall hearing a health warning may be isolated; have poor access to information and communication networks through which warnings are

disseminated; or simply do not remember hearing the warning. For those who did recall hearing the warnings, in general a majority considered the warnings appropriate in the sense that the warnings matched their experience of the heat. However, there were a considerable number of respondents who could not remember or could not say how well the warnings matched their experiences. The effects of poor recall in this could also have been exacerbated by poor recall of the specifics of the health warnings. Remembering hearing a health warning at some point is different to remembering when that warning was issued and the messages contained within. However, there was evidence to suggest that a majority of respondents *did* recall messages about how to maintain good health in the heat. The overall proportion was 89.2% with the lowest proportion in zone 6 at 85.3% and the highest proportion in zone 5 with 95.4%. This does not reflect the trend of high numbers of respondents indicating they did not know if warnings matched their experiences of the heat. It is possible that the question did not make sense to some respondents and confused them, making them unsure of how to interpret and answer the question.

As important as it is for appropriate health warnings to be disseminated during extreme heat, to be effective they must be considered by the community and the advice taken seriously. The "cry wolf" effect does have some evidence behind it – when populations lack knowledge about the health impacts of extreme heat or how to actively respond to warnings they can become desensitised to warnings (21, 22). In the case of this research most respondents did take warnings *very seriously* or *seriously*, upward of 70% in each climate zone. There was a significant association with climate zone. Zone 4 has the most respondents reporting taking warning only *somewhat seriously* – perhaps due to adaptation to warmer weather, but also more confident in their ability to cope, so they are not too concerned about the dangers. The cooler zones 5 and 6 each had a small number of respondents claiming to not take warnings seriously at all – perhaps relating to lack of previous negative experiences or a low level of perceived risk.

Taking warnings seriously would be expected to lead toward behaviour change, especially if those warnings are successful in conveying the risks and the actions that can be taken to improve resilience. When asked about behaviour changes in response to warnings, the results were quite mixed. In all zones between 20%-30% reported *not at all* changing their behaviours as a result of warnings. Possible reasons for this could be

that: (i) They may not have felt the need to do so, (ii) they were unaware of what more they could do, or (iii) they did not make any additional behaviours changes on top of what they would usually do during hot weather. However, in zone 6 there was a decline in the frequency of responses from disagreement to agreement. This indicates that respondents from the coolest zone were least likely to make substantial changes to their behaviour. Zone 4, the warmest zone, had the highest proportion of respondents who ranked their behaviour change at 4 or 5, meaning that they changed their behaviours *very much* as a result of the warnings. The association between climate zone and behaviour change ratings was significant. Responses were most likely influenced by experiences, interpretation of the question, and may be slightly linked to the results about how seriously respondents take the warnings. Householders from zone 4 were reported observing increases of heatwaves, and more than half reporting experiencing heatwaves *often*. It is possible that due to the increased exposure, and thus increased potential and risk for harm, respondents in zone 4 are more likely to change behaviours to avoid negative outcomes.

Overall, respondents in regional areas of South Australia are well aware of extreme heat events and the warnings that accompany them. Furthermore, there are excellent levels of recall and dissemination of messages, and most report taking them seriously – although they may not always result in dramatic changed in behaviour. There is need for further investigation into those whom are not being reached by messages or who are not taking health warnings seriously. It is clear that in a number of cases, climate does have an influence on the responses. Qualitative studies investigating past experiences and adaptation are an area for future study that could shed some further light on many of these results.

5.3 Strengths and Limitations

This research has looked at filling a gap in evidence by investigating an underrepresented sub-population, rural and regional communities, and making comparisons between climate zones. However, there were a number of limitations. Overall the sample size was small in each climate zone, and was reduced further in regards to the follow up question about health warnings. The sample size means that some trends were not clear and interpreting data became difficult in some situations. Furthermore, interpretations of some questions may have differed between individual respondents. In some cases, there

may have been confusion about the question, or a lack of interest in providing meaningful answers. Scales are sometimes not as helpful as categorical or ordinal data where an exact meaning can be applied to each value.

Another limitation previously mentioned was the issue with the timing of the survey. Results would have likely been different had the survey taken place during the summer. However, an investigation into these types of differences might be a topic of interest in the future. Recall would be stronger during summer, but perceptions might vary depending on how long ago the last extreme event occurred and its severity.

The use of the Köppen climate classification system may also be considered a limitation. Other ways of classifying climate could be considered. It would be interesting to investigate what this same data would show using a different climate classification method. In this case, the Köppen climate classification was used because of its availability, wide use, and suitability for mapping respondents to regions. The Köppen climate classification is based upon the link between climate and vegetation and takes into account long term climate and conditions (28). This means that even when two locations are separated by large distances, if they are in the same climate classification the general climate experiences and conditions will be similar throughout the seasons.

There were various confounding factors such as the differing age and sex distributions in each region, the potential for socio-economic status as mediator or confounder, and other unknown influences. Socio-economic status is especially important to consider, as regional areas often have a lower socio-economic status compared to metropolitan locations (29). Some regions are particularly known for agriculture, while others are mining locations, or places that attract tourism or are a popular retirement location. Culture and society also play a part in the formation of attitudes and behaviours.

6.0 Conclusion

Perceptions and responses to heatwaves and extreme heat events are affected by climate zone. Climate is an integral part of the equation that helps us understand vulnerability and how populations experience and respond to heat events. Understanding how people in regional areas perceive and respond to climate events can assist policy makers, public health professionals, and service provider's better tailor their approaches for heat warning and advice. Acknowledging the differences between different regions and climate types can also lead to fine-tuning and tailoring policies, interventions, or services in order to reach the most vulnerable.

The international body of research on heatwave research is broad and contains a variety of approaches and perspectives. The broad focus on differing climate zones rather than maximum or mean temperature sets this research apart from other studies in Australia and around the world. Furthermore, regional populations are less-studied compared to urban populations, and filling in that gap is a vital part in expanding this field of knowledge.

There is significant potential for further research in the future. Quantitative studies are one of the first steps in gathering evidence, and there is significant room for qualitative and mixed methods to help supplement the evidence. Improving our understanding of lived experiences of people in regional areas and in varied climate locations is essential to addressing some of the aspects of vulnerability and risk that can be influenced through evidence based interventions.

Acknowledgements

I would like to express my appreciation and gratitude to my supervisor, Susan Williams, for her unwavering patience and support. The advice and feedback you have provided me with has been instrumental to the success of this project. My most heartfelt thanks and best wishes for the future.

I would also like to thank Adriana Milazzo, the honours coordinator, for her dedication and time commitment to the program. Your support has been steadfast and your counsel empowering and comforting. Thank you for making this an enjoyable year and I hope you look forward to a well-deserved break.

7.0 References

1. Kovats RS, Hajat S. Heat stress and public health: a critical review. Annual Review of Public Health. 2008;29:41-55.
2. Nitschke M, Tucker GR, Hansen AL, Williams S, Zhang Y, Bi P. Impact of two recent extreme heat episodes on morbidity and mortality in Adelaide, South Australia: a case-series analysis. Environmental Health. 2011;10(1):1-9.
3. Luber G, McGeehin M. Climate Change and Extreme Heat Events. American Journal of Preventive Medicine. 2008;35(5):429-35.
4. Tong S, Ren C, Becker N. Excess deaths during the 2004 heatwave in Brisbane, Australia. International Journal of Biometeorology. 2010;54(4):393-400.
5. Bi P, Williams S, Hanson-Easey S, Nitschke M, Nairn J, Beattie C, et al. National Extreme Heat Warnings: Investigating regional temperature triggers and responses. 2015.
6. Bao J, Li X, Yu C. The Construction and Validation of the Heat Vulnerability Index, a Review. International Journal of Environmental Research and Public Health. 2015;12(7):7220-34.
7. Hajat S, Kosatky T. Heat-related mortality: A review and exploration of heterogeneity. Journal of Epidemiology and Community Health. 2010;64(9):753-60.
8. Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. Temperature and mortality in 11 cities of the eastern United States. American Journal of Epidemiology. 2002;155(1):80-7.
9. Carmona R, Díaz J, Mirón IJ, Ortiz C, Luna MY, Linares C. Mortality attributable to extreme temperatures in Spain: A comparative analysis by city. Environment International. 2016;91:22-8.
10. Li Y, Cheng Y, Cui G, Peng C, Xu Y, Wang Y, et al. Association between high temperature and mortality in metropolitan areas of four cities in various climatic zones in China: A time-series study. Environmental Health: A Global Access Science Source. 2014;13(1).
11. Gabriel KMA, Endlicher WR. Urban and rural mortality rates during heat waves in Berlin and Brandenburg, Germany. Environmental Pollution. 2011;159(8–9):2044-50.
12. Loughnan M, Nicholls N, Tapper N. Mortality–temperature thresholds for ten major population centres in rural Victoria, Australia. Health & Place. 2010;16(6):1287-90.
13. Hajat S, Kovats RS, Lachowycz K. Heat-related and cold-related deaths in England and Wales: Who is at risk? Occupational and Environmental Medicine. 2007;64(2):93-100.
14. Henderson SB, Wan V, Kosatsky T. Differences in heat-related mortality across four ecological regions with diverse urban, rural, and remote populations in British Columbia, Canada. Health & Place. 2013;23:48-53.
15. Burkart K, Schneider A, Breitner S, Khan MH, Krämer A, Endlicher W. The effect of atmospheric thermal conditions and urban thermal pollution on all-cause and cardiovascular mortality in Bangladesh. Environmental Pollution. 2011;159(8-9):2035-43.
16. Buscail C, Upegui E, Viel JF. Mapping heatwave health risk at the community level for public health action. International Journal of Health Geography. 2012;11:38.
17. Vaneckova P, Beggs PJ, Jacobson CR. Spatial analysis of heat-related mortality among the elderly between 1993 and 2004 in Sydney, Australia. Soc Sci Med. 2010;70(2):293-304.
18. Sheridan S, Dolney T. Heat, Mortality, and level of urbanization: measuring vulnerability across Ohio, USA. Climate Research. 2003;24:255-65.
19. Kovach MM, Konrad Ii CE, Fuhrmann CM. Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA. Applied Geography. 2015;60:175-83.
20. Hattis D, Ogneva-Himmelberger Y, Ratick S. The spatial variability of heat-related mortality in Massachusetts. Applied Geography. 2012;33:45-52.
21. Kalkstein AJ, Sheridan SC. The social impacts of the heat–health watch/warning system in Phoenix, Arizona: assessing the perceived risk and response of the public. International Journal of Biometeorology. 2007;52(1):43-55.

22. Sheridan SC. A survey of public perception and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. International Journal of Biometeorology. 2006;52(1):3-15.
23. ABCD. NCC 2016 Building Code of Australia - Volume 1. Canberra, Australia: The Australian Building Codes Board, 2016.
24. Bureau of Meterology. Gridded Köppen classification metadata: Bureau of Meteorology; 2006 [cited 2016]. Available from: http://www.bom.gov.au/climate/averages/climatology/gridded-data-info/metadata/md_koppen_classification.shtml.
25. Armitage P, Berry G, Matthews JNS. Statistical Methods in Medical Research (4). Chichester, GB: Wiley-Blackwell; 2008.
26. Hansen A, Bi P, Pisaniello D, Nitschke M, Tucker G, Newbury J, et al. Heat-health behaviours of older people in two Australian states. Australasian Journal on Ageing. 2015;34(1):E19-E25.
27. Hanna EG, Kjellstrom T, Bennett C, Dear K. Climate change and rising heat: population health implications for working people in Australia. Asia Pacific Journal of Public Health. 2011;23(2 Supplementary Material):14S-26.
28. Chen D, Chen HW. Using the Köppen classification to quantify climate variation and change: An example for 1901–2010. Environmental Development. 2013;6:69-79.
29. Australian Bureau of Statistics. ABS releases measures of socio-economic advantage and disadvantage (media release) 2008. Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/2033.0.55.001Media%20Release22006?opendocument&tabname=Summary&prodno=2033.0.55.001&issue=2006&num=&view=.

8.0 Appendices

8.1 Appendix A

[removed for copyright reasons]

See Appendix B

8.2 Appendix B