The Australia Institute
Research that matters.

Vulnerability to extreme heat

The inequitable impacts of a warming Australia

Extreme heat is the number one cause of weather-related illness and death in all parts of Australia, except Tasmania. Older, poorer, and sicker people are more vulnerable to the effects of extreme heat. This report identifies the locations around Australia in which the greatest number of vulnerable people will be affected by extreme heat. Targeting these areas for support will ensure the greatest number of vulnerable people are helped during periods of extreme heat.

Discussion paper

Minh Ngoc Le
Alexia Adhikari
Morgan Harrington

November 2024

The Australia Institute – Research that matters

Established in 1994, The Australia Institute is an independent public policy think tank with offices in Canberra, Hobart, Melbourne and Adelaide providing intellectual and policy leadership across a broad range of economic, social and environmental topics. We conduct research that drives the public debate and secures policy outcomes that make Australia better – research that matters.

The Australia Institute is funded by donations from philanthropic trusts and individuals, as well as grants and commissioned research from business, unions and non-government organisations. We do not accept donations or commissioned work from political parties. With no formal political or commercial ties, the Institute maintains its independence while advancing a vision for a fairer Australia.

Donations to our Research Fund are tax deductible, and can be made via our website or by calling the Institute:

Level 1, Endeavour House,
1 Franklin St Canberra,
ACT 2601
Tel: (02) 6130 0530
Email: mail@australiainstitute.org.au
Website: www.australiainstitute.org.au

Acknowledgement of Country

The Australia Institute recognises the ancestral connections and custodianship of Traditional Owners throughout Australia. We pay respect to Aboriginal and Torres Strait Islander cultures and to Elders past and present.

Contents

Summary

Extreme heat disproportionately affects vulnerable people, who may lack adequate access to cooling facilities, suffer from chronic health conditions, or face socioeconomic barriers that limit their ability to cope with extreme hot conditions. Vulnerable populations are at heightened risk as the duration, frequency, and intensity of heatwaves increases because of climate change.

A 2023 report by the Australian Institute of Health and Welfare (AIHW) shows that excessive natural heat is the leading cause of weather-related hospitalisations and death in all states and territories in Australia, except Tasmania. Unless action is taken to mitigate the effects climate change, over the next 50 years Australia can expect rates of heat-related illness and death to increase.

This report identifies the locations around Australia in which large numbers of people will suffer from intensifying heat because of their age, illness, or income level. It identifies the locations that have both a high concentration of vulnerable people as well as a high likelihood of experiencing extreme hot weather as the effects of climate change intensify.

In this report, we define “extreme” heat as days over 35°C because this is the critical temperature threshold at which exposure of six hours or more can result in death. To determine the number of days over 35°C that will occur in the future (by 2030 and 2050) we use data from the CSIRO and the Bureau of Meteorology (BoM). This data is, in turn, based on the Representative Concentration RCP 4.5, ‘intermediate emissions’ scenario from the Intergovernmental Pannel on Climate Change’s (IPCC) Fifth Assessment Report, which closely reflects the outcomes we might see if all countries implement their current commitments under the 2015 Paris Agreement.

We use Australian Bureau of Statistics (ABS) statistics to define vulnerable people as those living below the poverty line who also have at least one long-term health issue and/or are aged 65 and older. We use the same ABS data to calculate the concentration of vulnerable people in locations around Australia. We discuss the effects of heat on vulnerable populations at four geographical levels: smaller ‘locations’ (the same as the ABS’s SA2s), larger ‘areas’ (the same as the ABS’s SA4s), greater metropolitan regions, and states and territories. We use heat and vulnerability indicators to give each location a score out of 100, and then ranked each location from least to most vulnerable.

Our report finds that vulnerability to heat is unevenly distributed across Australia. In most states and territories, coastal areas tend to be cooler and have lower concentrations of vulnerable people than inland and rural areas. This means that extreme heat poses a greater threat to outer-urban and rural areas than inner-urban areas, especially those near the sea.

The states and territories most vulnerable to extreme heat are the Northern Territory, South Australia and Western Australia. In the Northern Territory, 78% of locations are highly vulnerable to extreme heat, as are 57% of locations in South Australia and 52% of locations in Western Australia. In contrast, we have classified the vulnerability to heat of almost all locations in the ACT as 'Medium low', and of all locations in Tasmania as 'Low'.

Climate change is exacerbating existing inequalities and disproportionately impacting the most vulnerable Australians. While all vulnerable people would benefit from support to avoid the risks associated with heat exposure, this report identifies the locations of greatest need because they have a higher concentration of vulnerable people and face a higher likelihood of extreme heat.

Introduction

Increasing global temperatures mean that heatwaves are growing in frequency, duration and intensity. Australia is no exception.[1] During the Northern Hemisphere summer of 2024, countries across Europe, Africa, North America and Asia grappled with intense heatwaves– that resulted in closures of tourist attractions and schools, heat-related hospitalisations and even deaths.[2] If global average temperatures continue to rise, heatwaves will only worsen for Australia. So-called 'lethal heat' means that some areas of northern Australia are at risk of becoming 'unlivable'.[3]

Extreme heat poses a heightened threat to people who are vulnerable because of poverty, illness, and/or age. Vulnerable groups may lack adequate access to cooling facilities, suffer from chronic health conditions that are exacerbated by heat, or face socioeconomic barriers that limit their ability to cope with extremely hot conditions.

Extreme heat can exacerbate or even cause many serious health problems – it can even kill. Ambulance call outs can increase by up to 10% during heatwaves.[4] A 2023 report by the Australian Institute of Health and Welfare (AIHW) shows that excessive natural heat is the leading cause of hospitalisations and death from weather-related injury in all states and

[1] Grose, Gergis and Canadell (2021) *Climate change has already hit Australia. Unless we act now, a hotter, drier and more dangerous future awaits, IPCC warns*, https://science.anu.edu.au/news-events/news/climate-change-has-already-hit-australia-unless-we-act-now-hotter-drier-and-more;

[2] Barlow and Basara (2024) *Extreme heat waves broiling the US in 2024 aren't normal: How climate change is heating up weather around the world*, https://theconversation.com/extreme-heat-waves-broiling-the-us-in-2024-arent-normal-how-climate-change-is-heating-up-weather-around-the-world-234249; Al Jazera (2024) *Greece shuts Acropolis, schools as it braces for 43°C heatwave*, https://www.aljazeera.com/news/2024/6/13/greece-shuts-acropolis-schools-as-it-braces-for-43c-heatwave; Associated Press (2024) *Severe heatwave in Iran forces shops and public institutions to close*, https://www.theguardian.com/world/article/2024/jul/27/severe-heatwave-in-iran-forces-shops-and-public-institutions-to-close; Associated Press (2024) *July ends 13-month streak of global heat records, but experts warn against relief*, https://www.theguardian.com/environment/article/2024/aug/08/global-extreme-heat-record; Cassidy (2024) *Heat Wave in East Africa*, https://earthobservatory.nasa.gov/images/152600/heat-wave-in-east-africa

[3] Kirk (2024) *Northern parts of Australia to suffer from 'lethal heat' in coming decades*, https://www.theaustralian.com.au/breaking-news/northern-parts-of-australia-to-suffer-from-lethal-heat-in-coming-decades/news-story/f8797d1f6a447393cf876e5e27868dca#; Australian Security Leaders Climate Group (2024) *Too Hot to Handle: Case study: Northern Exposure*, https://www.aslcg.org/reports/too-hot-to-handle/

[4] Oberai et al (2024) 'Preparing for a hotter climate: A systematic review and meta-analysis of heatwaves and ambulance callouts in Australia', *Australian and New Zealand Journal of Public Health*, https://doi.org/10.1016/j.anzjph.2023.100115

territories in Australia except Tasmania.[5] It also shows that people aged 65 and older are the most likely to be hospitalised because of heat.[6] In the next 50 years, if temperatures continue to rise, heat-related deaths are projected to increase across major Australian cities.[7]

The people most vulnerable to extreme heat are those who not only have health conditions, but who are also aged 65 and older and/or are experiencing poverty.[8] As spending on electricity, especially for cooling, has increased during the cost-of-living crisis,[9] many people reliant on government payments are cutting back on cooling to lower their energy bills.[10] Energy bills are one of the top three most stressful bills for Australians.[11] As a proportion of household income, lower income households spend more on utilities (including electricity for cooling) than medium and higher income households,[12] which means they have less capacity to pay increasing costs of air-conditioning.

This report identifies the locations across Australia that have the highest number of people vulnerable to intensifying heat because of age, illness, or income level. While the Australian

[5] Australian Institute of Health and Welfare (AIHW) (2023) *Let's talk about the weather: injuries related to extreme weather*, https://pp.aihw.gov.au/reports/injury/extreme-weather-injuries/contents/an-overview-of-extreme-weather-related-injuries

[6] AIHW (2023) *Let's talk about the weather: injuries related to extreme weather*

[7] IPCC (2022) *Climate change 2022: Impacts, adaptation, and vulnerability, contribution of Working Group II to the sixth assessment report of the Intergovernmental Panel on Climate Change*, p 63, doi:10.1017/9781009325844.

[8] Cunningham and Rutherford (2023) *5 reasons to check on your elderly neighbour during a heatwave*, https://theconversation.com/5-reasons-to-check-on-your-elderly-neighbour-during-a-heatwave-196218; Nicholas (2023) *'Silent killer': more than half of heatwave deaths are in disadvantaged areas – now Australian councils are fighting back*, https://www.theguardian.com/news/datablog/2023/oct/29/silent-killer-more-than-half-of-heatwave-deaths-are-in-disadvantaged-areas-now-australian-councils-are-fighting-back; Quick (2024) *The impacts of extreme heat events on non-accidental, cardiovascular, and respiratory mortality: An analysis of 12 Canadian cities from 2000 to 2020*, https://www150.statcan.gc.ca/n1/pub/82-003-x/2024006/article/00001-eng.htm

[9] Household spending rose 0.4% in the December 2023 to March 2024 summer period. According to the ABS, "the rise in essential spending was driven by spending on electricity, gas and other fuels, as higher than usual summer temperatures increased demand for cooling." See ABS (2024) *Australian national accounts: national income, expenditure and product*, https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/mar-2024

[10] ACOSS (2023) *Energy and cost of living snapshot*, https://www.acoss.org.au/media_release/urgent-action-needed-to-help-people-afford-energy-bills-ahead-of-horror-summer/

[11] Sudarshan and Wallis (2023) *Australian household spending statistics*, https://www.finder.com.au/insights/australian-household-spending-statistics

[12] ABS (2017) *Household expenditure survey, reference period 2015–16*, https://www.abs.gov.au/statistics/economy/finance/household-expenditure-survey-australia-summary-results/latest-release; Chandrashekeran et al (2024) 'Electrification and lower-income households in Australia: An integrated analysis of adaptive capacity and hardship', *Energy Research & Social Science*, https://doi.org/10.1016/j.erss.2024.103688

Government's 2024 Health-Heat Risk Index uses a similar approach,[13] our report focuses on the effects of increasing heat where vulnerable populations are concentrated.

While governments at all levels will need to take responsibility for any location that experiences extreme heat, areas with a greater concentration of vulnerable people will require additional support.

Our report shows that coastal areas are generally less vulnerable to extreme heat than inland regions, and rural areas are generally more vulnerable than urban areas. Of all states and territories, the Northern Territory is the most vulnerable to extreme heat, with 78% of locations at a high level of vulnerability. In contrast, the vulnerability of all locations in Tasmania is low, making it the state least vulnerable to extreme heat.

By identifying locations most vulnerable to extreme heat, this report suggests that targeted interventions could be designed to protect vulnerable people from intensifying heat.

[13] Australian Climate Service (2024) *Heatwaves in Australia*, https://storymaps.arcgis.com/stories/ad21a54268e24dacae0f77df628e9285

Method

This report identifies the locations across Australia where extreme heat poses the greatest threat to the greatest number of vulnerable people. It identifies the locations that have both a high concentration of vulnerable people and which are at a high risk of extreme heat as global temperatures increase.

Using data from the ABS Census, our report defines vulnerable people as those living below the poverty line,[14] who also have at least one long-term health issue,[15] and/or who are 65 years and older.[16] The concentration of vulnerable people is measured by calculating the number of vulnerable people in a location (indicator 1) and the percentage of vulnerable people in a location (indicator 2).

To estimate the risk that extreme heat poses to different parts of Australia, we calculated the number of days over 35°C are projected by the CSIRO to occur by 2030 (indicator 3) and by 2050 (indicator 4).[17] The CSIRO bases its forecast on the different global climate action scenarios outlined in the IPCC's Fifth Assessment Report.[18] Within these different scenarios, we have made our estimations based on the Representative Concentration RCP 4.5, 'intermediate emissions' scenario, as this most closely reflects the outcomes we could expect see if all countries implement their current commitments under the Paris Agreement.[19] We have used 35°C as the measurement of "extreme heat" because it is the critical temperature threshold at which exposure of six hours or more can result in death.[20]

Figure 1 shows how these four indicators feed into our ranking of vulnerability.

[14] ABS (2023) *2021 Census-culture diversity- employment and income*, https://tablebuilder.abs.gov.au/webapi/jsf/tableView/tableView.xhtml

[15] ABS (2023) 2021 *Census-culture diversity- Health*, https://tablebuilder.abs.gov.au/webapi/jsf/tableView/tableView.xhtml

[16] ABS (2023) *2021 Census-culture diversity- Age and sex*, https://tablebuilder.abs.gov.au/webapi/jsf/tableView/tableView.xhtml

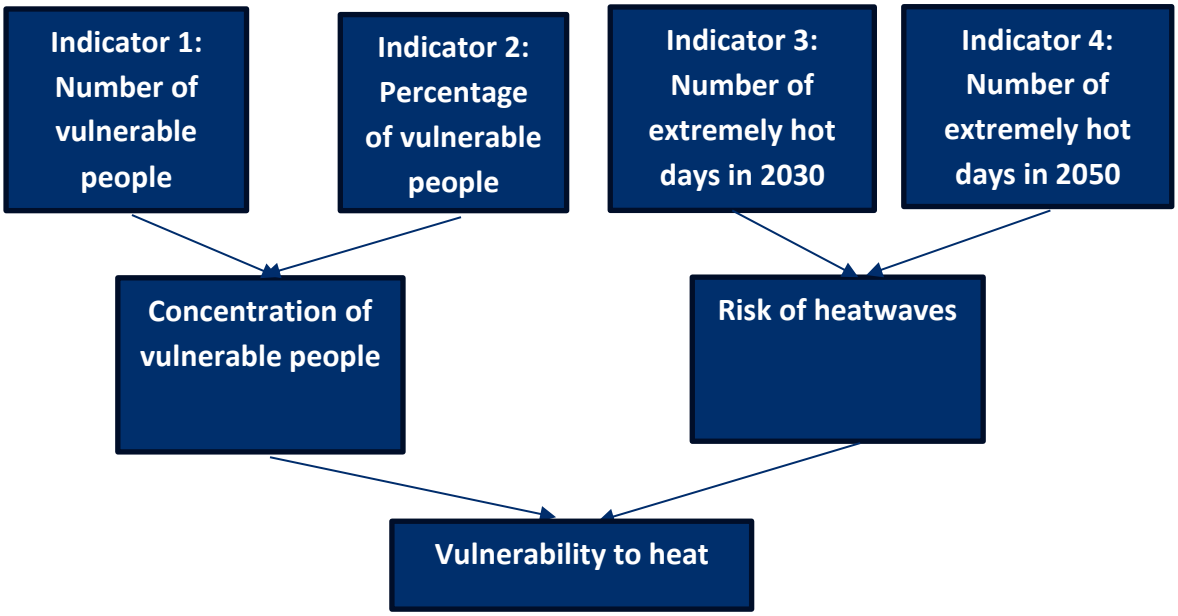
[17] CSIRO (2018) *Climate projections*, provided on request.

[18] IPCC (2014) *Climate change 2014: synthesis report. Contribution of working groups i, ii and iii to the fifth assessment report of the Intergovernmental Panel on Climate Change*, p 10, https://www.ipcc.ch/report/ar5/syr/; The IPCC scenarios for global climate action: Representative Concentration Pathway (RCP) 2.6 ("low emissions"), RCP 4.5 ("intermediate emissions") and RCP 8.5 ("high emissions").

[19] Climate Council (2024) *Climate Heat Map of Australia*, p15, https://www.climatecouncil.org.au/resources/heatmap/

[20] Australian Security Leaders Climate Group (2024) *Too hot to handle: The scorching reality of Australia's climate-security failure*, https://www.aslcg.org/reports/too-hot-to-handle/

Figure 1: Measuring vulnerability to heat for each location (SA2)



The locations in this report are the geographical areas defined by the ABS as Statistical Area Level 2s (SA2s).[21] In Australia, there are 2,473 SA2s. However, this includes 19 SA2s in which populations are difficult to define geographically (such as people who are in transit or have no fixed address), and five SA2s for which there is insufficient information about the number of days forecast over 35°C. We have therefore excluded these 24 SA2s from our dataset, which means we have analysed a total of 2,449 SA2s. These 2,449 locations fall within 89 larger geographical areas defined by the ABS as Statistical Area Level 4s (SA4s). In this report, we call these SA4s 'areas'.

For each location (SA2), all four indicators were scored between 0 (lowest) and 100 points (highest) using a min-max normalisation method. This allowed us to compare different indicators on the same scale, even though they vary widely and are measured differently. For example, the number of days over 35°C ranges from 0 to more than 260, and the number of vulnerable people ranges from 0 to 6,400. By normalising these values, we make them directly comparable.

The formula for the normalised score of each indicator for each SA2 is as follows:

[21] After national and state and territory area categorisations, geographical locations are categorised into four main levels based on population size. Of these, Statistical Areas Level 1 (SA1) is the smallest with usually between 200 to 800 people, and Level 4 (SA4) is the largest, with usually more than 100,000 people. SA2s generally have between 3,000 and 25,000 people. Each level is larger in population size than the last and consists of a collection of the previous levels. For example, whole SA1s aggregate to form an SA2. ABS (2021) *Australian Statistical Geography Standard (ASGS) Edition 3*, https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/latest-release

$$S_i = \frac{X - X_{min}}{X_{max-}X_{min}} * 100$$

Where: S_i presents the four individual scores (S1, S2, S3, S4) for each SA2.

X is the value of the indicator for a specific SA2.

X_{max} is the maximum value of the indicator among SA2.

X_{min} is the minimum value of the indicator among SA2.

We then calculated the overall score for each SA2 as the geometric mean of the four individual scores by multiplying the four individual scores together, and then taking the fourth root of the product. The formula of the overall score can be written as follows:

$$S = \sqrt[4]{S1 * S2 * S3 * S4}$$

Where: S is the overall score for each SA2.

During the scoring process, some locations (SA2s) ended up with a very high overall score simply because they had *one* particularly high value (i.e. number of vulnerable people, or number of days over 35°C) even though other indicators were low. Consequently, the overall score of these particular areas did not accurately reflect their relative level of vulnerability to heat. For example, the location of Alligator (NT) is projected to experience 201 days over 35°C by 2030, and 229 days over 35°C by 2050 – this is the fourth highest number of hot days projected for anywhere in Australia. However, this location has a low population (611 vulnerable people). Without adjustment, this small town would have been ranked the most vulnerable location in Australia, ahead of Mount Isa (QLD) which has more than twice the number of vulnerable people (1,428), and only slightly fewer days over 35°C by 2030 (167), and days over 35°C by 2050 (184). To address this issue, if the value for any one indicator was less than 10% of the maximum value of that indicator we reduced the overall score of that location by 20%. For example, Bribie Island (QLD) has the highest number of vulnerable people of any location in Australia (6,400), but the number of projected days over 35°C degrees by 2030 is just 2.1, which is about 1% of the highest location (Derby, West Kimberley, WA, which is projected to have 254.5 days over 35°C degrees by 2030).

We made these adjustments because our aim is to identify the parts of Australia in which the greatest number of people will require support. We choose a 10% threshold because it captures outliers that are low but still significant enough to affect the overall score. We reduced the overall score of these outliers by 20% to because this lowered their undue influence on overall scores, which ensured that overall scores reflected a more balanced view of vulnerability to heat. Limiting reductions to 20% meant that we did not introduce unwanted differentiation between locations. Doing this also helped moderate the impact of disproportionately low indicators on overall scores.

Once we had made our calculations and adjustments, we sorted all locations by overall score, from highest to the lowest. The location with the highest overall score is the most vulnerable to heat, and the SA2 with the lowest overall score is the least vulnerable to heat. Our scores reflect the locations in which a significant concentration of vulnerable people are likely to need additional support to prevent heat-related health and social complications.

A high overall score indicates that a location has both a high concentration of vulnerable people, and high likelihood of days over 35°C. In contrast, locations with a low overall score have one of following characteristics:

- A low concentration of vulnerable people but a high likelihood of days over 35°C.
- A high concentration of vulnerable people but a low likelihood of days over 35°C.
- A low concentration of vulnerable people and a low likelihood of days over 35°C.

Based on their overall score, we further classified each location into five levels of vulnerability:

- High: 81st – 100th percentile
- Medium high: 61st – 80th percentile
- Medium: 41st – 60th percentile
- Medium low: 21st – 40th percentile
- Low: 1st – 20th percentile

We have used these scores consistently in all levels of our analysis (location, area, state and territory, national).

Our results are presented in dot charts (scatterplots). Each dot represents a location, while each colour represents a level of vulnerability to heat. The higher a location appears on the vertical axis of a scatterplot, the more vulnerable it is to heat. For larger, more populated states, we have also presented our results on maps.

Results

NATIONAL

Of all the states and territories in Australia, the Northern Territory has the highest proportion of highly vulnerable locations (78%), followed by South Australia (57%) and Western Australia (52%). In contrast, the vulnerability level of almost all locations in the ACT is either medium low or low, and in Tasmania all locations have a low level of vulnerability. (Table 1).

Table 1: Number and percentage of locations classified as 'High', by state and territory

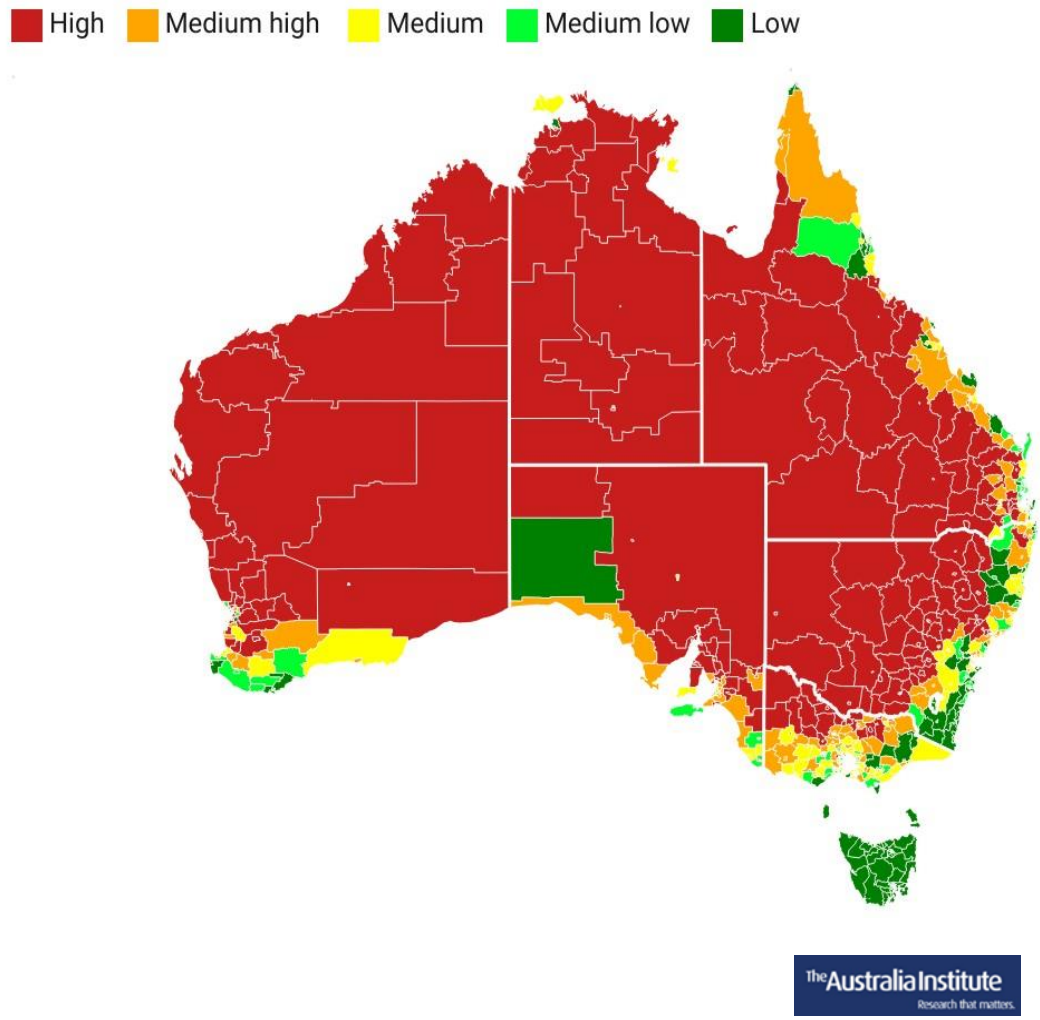
State/Territory	No. of highly vulnerable locations	Total locations	Percent of locations considered highly vulnerable
Northern Territory	53	68	78%
South Australia	100	174	57%
Western Australia	138	265	52%
New South Wales	91	642	14%
Queensland	63	545	12%
Victoria	45	522	9%
Australia Capital Territory	0	134	0%
Tasmania	0	99	0%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Across Australia, 20% of locations are highly vulnerable to extreme heat. However, these locations are based on population size, not geographical size. In terms of geographical coverage, most of Australia is highly vulnerable to extreme heat. In general, eastern and southern coastal locations are less vulnerable to increases in temperatures compared to inland areas. Rural locations are more vulnerable to heat than urban ones (see Figure 2).

Despite being part of the notoriously hot and dry Nullarbor Plain, our calculations show that one location in north-western South Australia has a low vulnerability ranking. This is shown in dark green in Figure 2. This is because, according to ABS data, just seven people can be considered vulnerable. Because of the way we have weighted our indicators, this location became less vulnerable to heat compared than other locations with a similar number of extremely hot days. Although vulnerable people in this location also need assistance to avoid heat-related health risks, other locations have a higher concentration of vulnerable people.

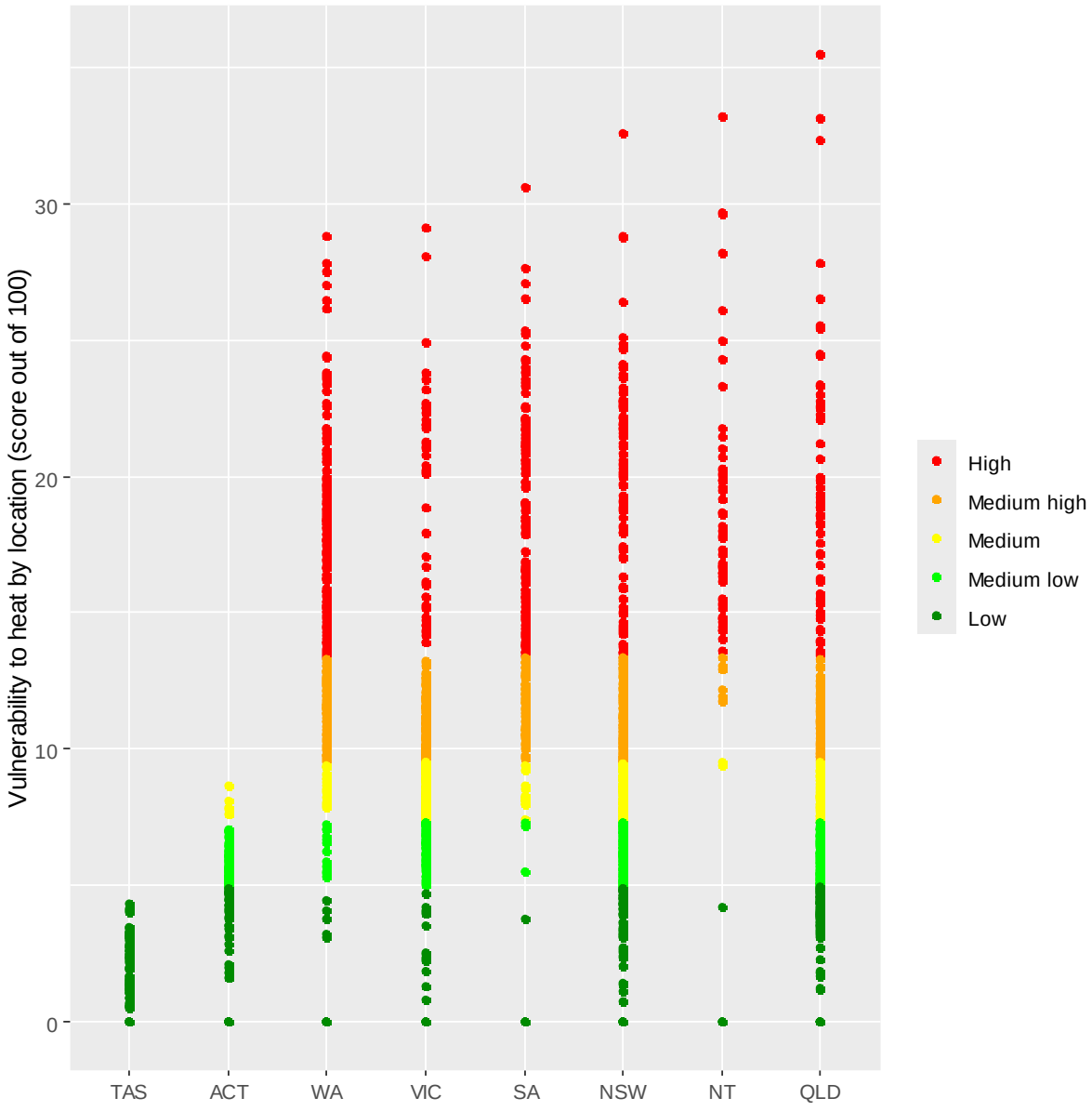
Figure 2: Vulnerability to heat by location, Australia[22]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: PSMA Australia Limited.

[22] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/x3auL/11/

Chart 1: Vulnerability to heat by location, state/territory



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Of the top 10 most vulnerable locations in Australia, more than half are in Queensland and the Northern Territory. The number one most vulnerable location in Australia is Mount Isa, Queensland (Table 2).

Table 2: The Top 10 most heat vulnerable locations in Australia

Ranking	Location	Area	State/ Territory
1	Mount Isa	Outback	QLD
2	Katherine	Outback	NT
3	Charters Towers	Townsville	QLD
4	Broken Hill	Far West and Orana	NSW
5	Barcaldine - Blackall	Outback	QLD
6	Port Pirie	Barossa - Yorke - Mid North	SA
7	Alligator	Outback	NT
8	Humpty Doo	Darwin	NT
9	Mildura - North	North West	VIC
10	Derby - West Kimberley	Outback (North)	WA

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

In Table 3, the vulnerability of each state and territory has been determined by averaging the overall scores of every location within each state and territory. The Northern Territory has the highest overall score (16.16), followed by South Australia (14.85) and Western Australia (13.48). In contrast, Tasmania has the lowest score (1.65).

Table 3: Average overall vulnerability score by state and territory

State/Territory	Average overall score of all locations
Northern Territory	16.16
South Australia	14.85
Western Australia	13.48
Victoria	9.62
New South Wales	9.31
Queensland	7.62
Australian Capital Territory	4.22
Tasmania	1.65

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

NORTHERN TERRITORY

Table 4 shows that of the 68 locations in the Northern Territory, the majority (78%) are highly vulnerable. A further 9% can be classified as medium high, 3% as medium, and 10% as low.[23] Although the population of the Northern Territory is smaller than other states and territories, the CSIRO forecast that, in coming decades, the Northern Territory will experience up to 232 days a year over 35°C by 2050. This very high number of extreme heat days is what makes the Northern Territory more vulnerable to extreme heat than any other state or territory in Australia.

Table 4: Vulnerability to heat by location, Northern Territory

	High	Medium high	Medium	Medium low	Low	Total
Northern Territory						
Number of locations	53	6	2	0	7	68
Percentage of locations	78%	9%	3%	0%	10%	100%
Darwin						
Number of locations	33	5	0	0	6	44
Percentage of locations	75%	11%	0%	0%	14%	100%
Northern Territory Outback						
Number of locations	20	1	2	0	1	24
Percentage of locations	83%	4%	8%	0%	4%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Table 5: Top 10 most heat vulnerable locations in the Northern Territory

Rank	Location	Area
1	Katherine	Northern Territory - Outback
2	Alligator	Northern Territory - Outback
3	Humpty Doo	Darwin
4	Gulf	Northern Territory - Outback
5	Tanami	Northern Territory - Outback
6	Elsey	Northern Territory - Outback
7	Victoria River	Northern Territory - Outback
8	Tennant Creek	Northern Territory - Outback
9	West Arnhem	Northern Territory - Outback
10	Weddell	Darwin

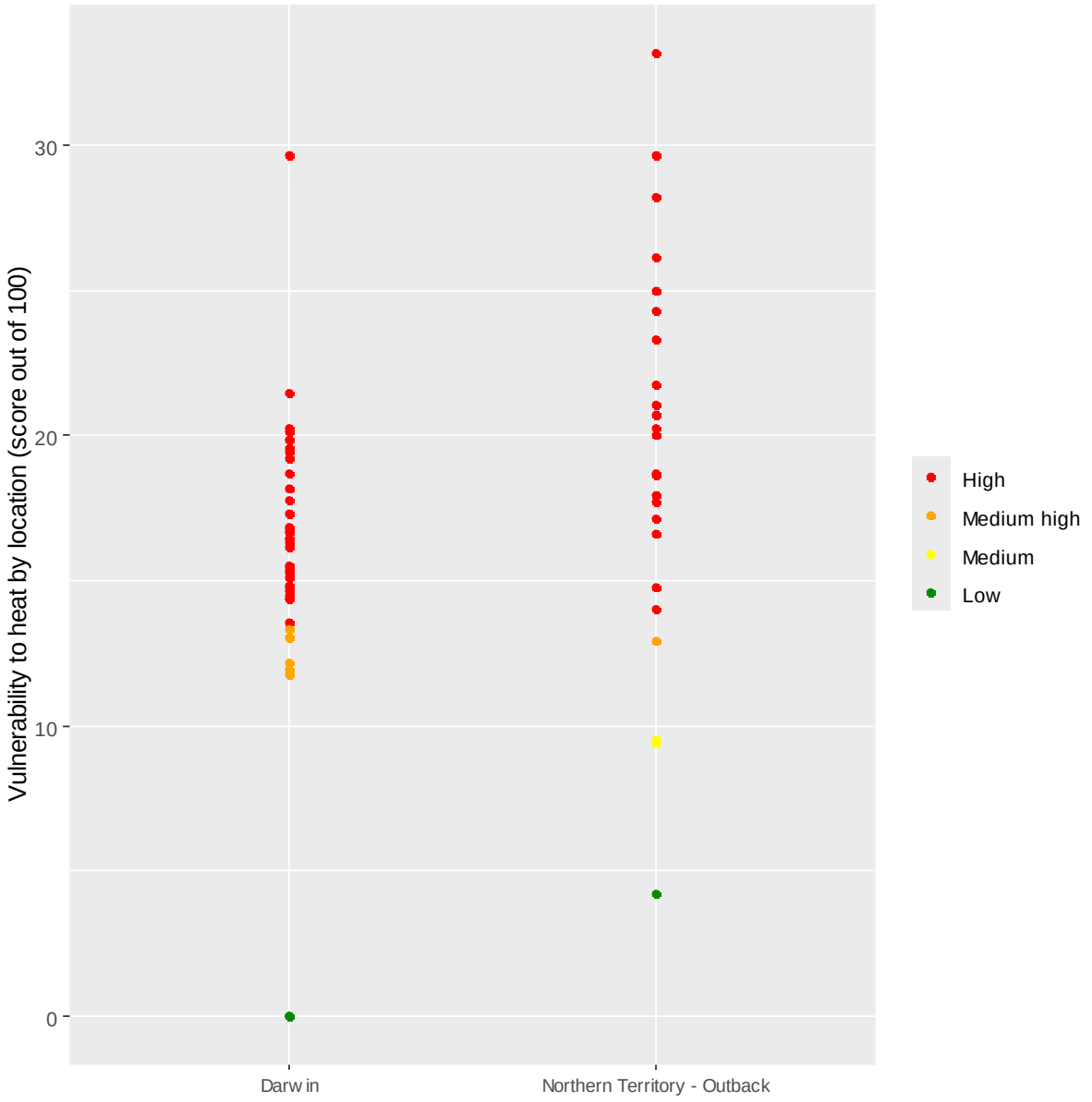
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

[23] Some of the 10% of locations in the NT classified as low were not ranked higher because they have very small populations and very low numbers of vulnerable people (either at, or very close to, zero). But this does not mean they are not affected by high temperatures, or that there aren't any vulnerable people in these locations.

Darwin and the Northern Territory Outback

The Outback Northern Territory area is more vulnerable to heat than the Darwin area. Table 4 (above) and Chart 2 (below) show that 83% of the locations in the Outback area, and 75% of the locations in the Darwin area have a high level of vulnerability. Among the top 10 most vulnerable locations in the Northern Territory, eight are in the Outback area and two are in the Darwin area (Table 5). The average overall score of locations in the Outback area is 19.4, compared to 14.4 in the Darwin area.

Chart 2: Vulnerability to heat by location, Northern Territory



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

SOUTH AUSTRALIA

Table 6 shows that more than half of the locations in South Australia are highly vulnerable to extreme heat (57%). Of the remaining locations, the vulnerability level is medium high for 27%, medium for 8%, medium low for 2%, and low for 5%.

Table 6: Vulnerability to heat by location, South Australia

	High	Medium high	Medium	Medium low	Low	Total
South Australia						
Number of locations	100	47	14	4	9	174
Percentage of locations	57%	27%	8%	2%	5%	100%
Greater Adelaide						
Number of locations	64	33	7	1	7	112
Percentage of locations	57%	29%	6%	1%	6%	100%
The rest of South Australia						
Number of locations	36	14	7	3	2	62
Percentage of locations	58%	23%	11%	5%	3%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Table 7: Top 10 most heat vulnerable locations in South Australia

Ranking	Location	Area
1	Port Pirie	Barossa - Yorke - Mid North
2	Whyalla	South Australia - Outback
3	Port Augusta	South Australia - Outback
4	Gawler - South	Adelaide - North
5	Waikerie	South Australia - South East
6	Murray Bridge	South Australia - South East
7	Peterborough - Mount Remarkable	Barossa - Yorke - Mid North
8	Salisbury	Adelaide - North
9	Barmera	South Australia - South East
10	Wakefield - Barunga West	Barossa - Yorke - Mid North

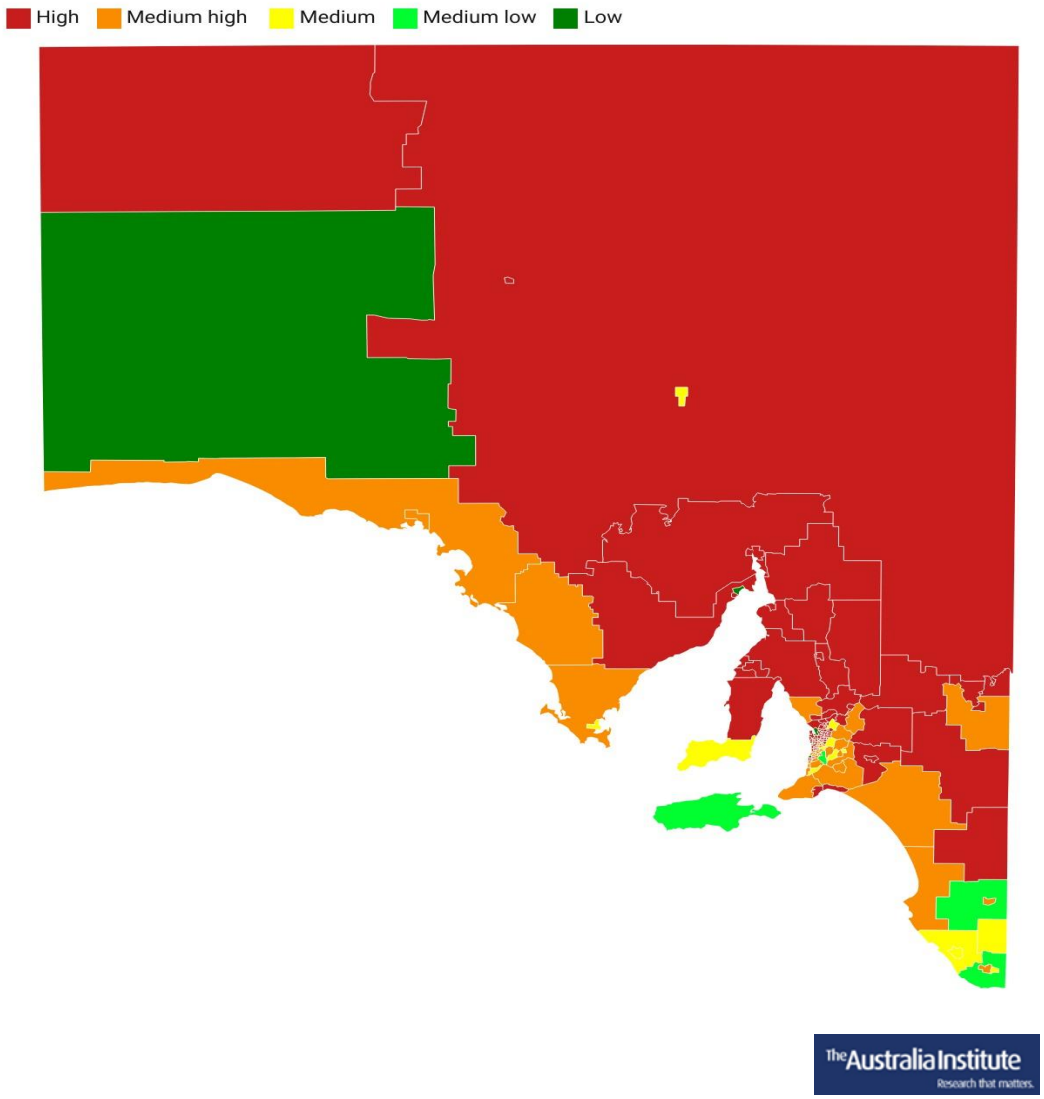
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

As Figure 3 (below) shows, inland locations are more vulnerable to extreme heat than those nearer the coast.

Despite being part of the notoriously hot and dry Nullarbor Plain, our calculations show that one location in north-western South Australia (official known as Western) has a low-level of vulnerability to heat. This is shown in dark green in Figure 3. This is because, according to ABS data, just seven people can be considered vulnerable. Because of the way we have weighted our indicators, this location became less vulnerable to heat compared than other

locations in South Australia with a similar number of extremely hot days. Although vulnerable people in this location also need assistance to avoid heat-related health risks, other locations have a higher concentration of vulnerable people.

Figure 3: Vulnerability to heat by location, South Australia[24]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

Greater Adelaide and the rest of South Australia

As shown in Table 6 (above), a similar percentage of locations in Greater Adelaide and the rest of South Australia are highly vulnerable – 57% for Greater Adelaide and 58% for the rest of South Australia. However, eight of the ten most vulnerable locations in South Australia

[24] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/uDZeE/6/

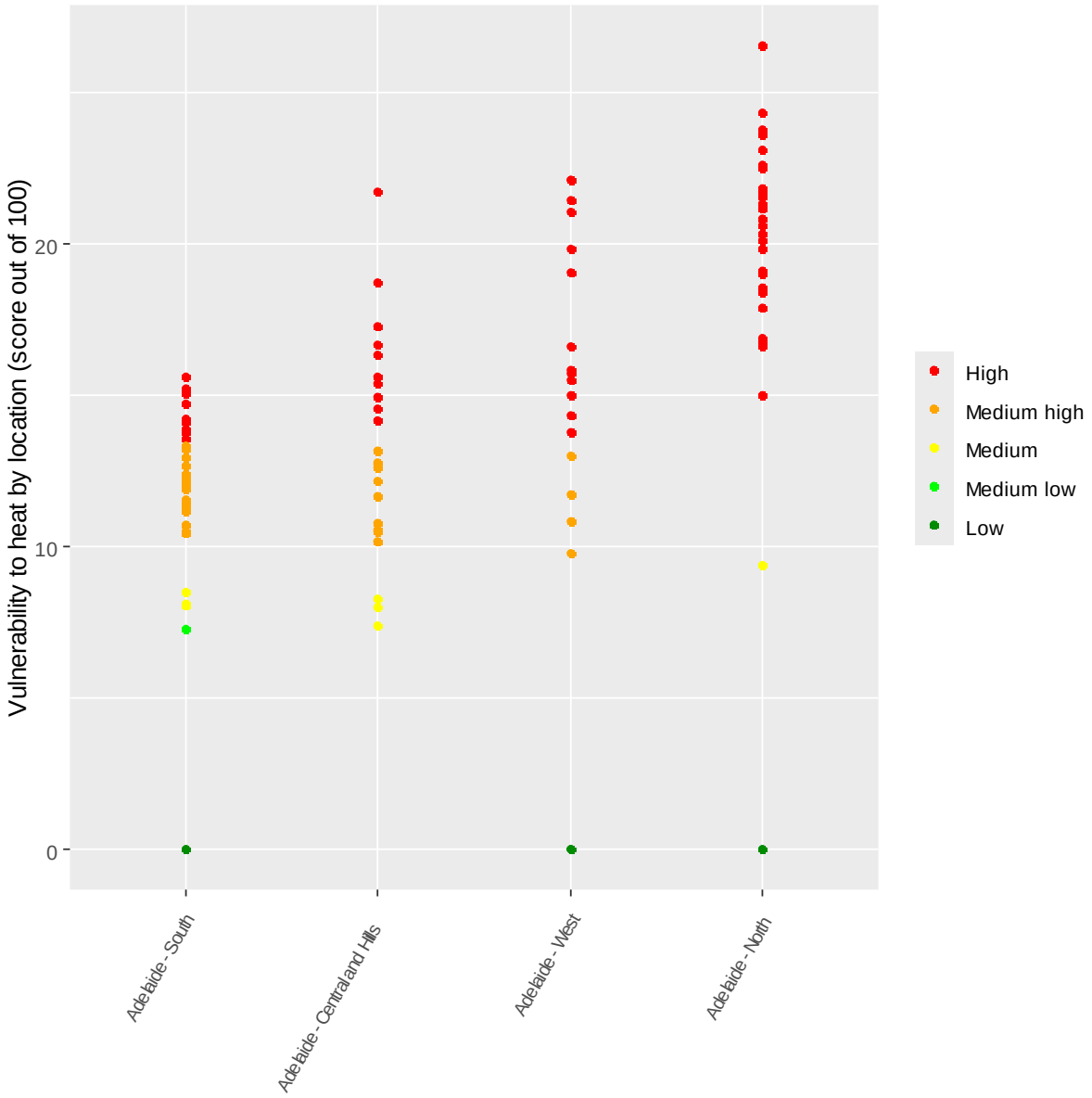
are outside of Greater Adelaide (Table 7). The average overall score of all locations in Greater Adelaide is 14.4, compared to 15.6 for the rest of South Australia.

Greater Adelaide

Of the four areas that make up Greater Adelaide, Adelaide North is the most vulnerable to extreme heat. The vulnerability level of nearly all locations in this area is high (Chart 3 below). A look at the ABS's map for Adelaide North shows that this area is inland, has sparse tree coverage and a large number of buildings, which may exacerbate the effects of extreme heat for vulnerable people. In contrast, Adelaide South is the part of the city least vulnerable to extreme heat. It is near the coast and has better tree coverage, which help keep temperatures down.[25]

[25]ABS (2024) *Data by region: search by map*, https://dbr.abs.gov.au/

Chart 3 : Vulnerability to heat by location, Greater Adelaide



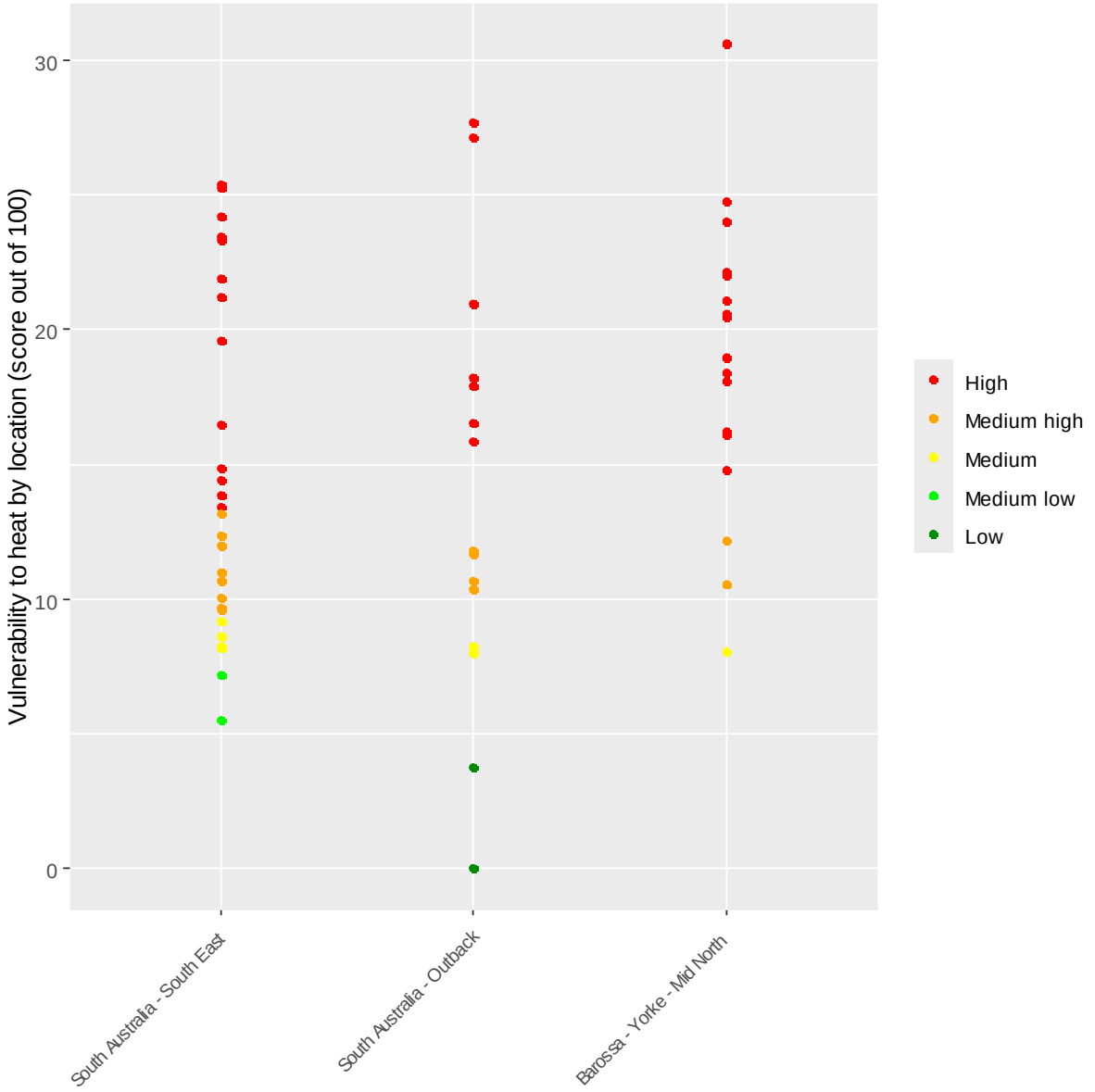
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

The rest of South Australia

The majority of locations within the three areas that make up the rest of South Australia (outside of Greater Adelaide) are highly vulnerable to heat. Of these three areas, the most vulnerable is Barossa - Yorke - Mid North (Chart 4). A look at the ABS's map for this area shows that it is inland and has sparse tree coverage, which may exacerbate the effects of extreme heat for vulnerable people.[26]

[26]ABS (2024) *Data by region: search by map*, https://dbr.abs.gov.au/

Chart 4: Vulnerability to heat by location, the rest of South Australia



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

WESTERN AUSTRALIA

Table 8 shows that more than half of the 265 SA2s in Western Australia are highly vulnerable to heat. Of the remainder, the vulnerability level is medium high for 26%, medium for 7%, medium low for 5%, and low for 11%.

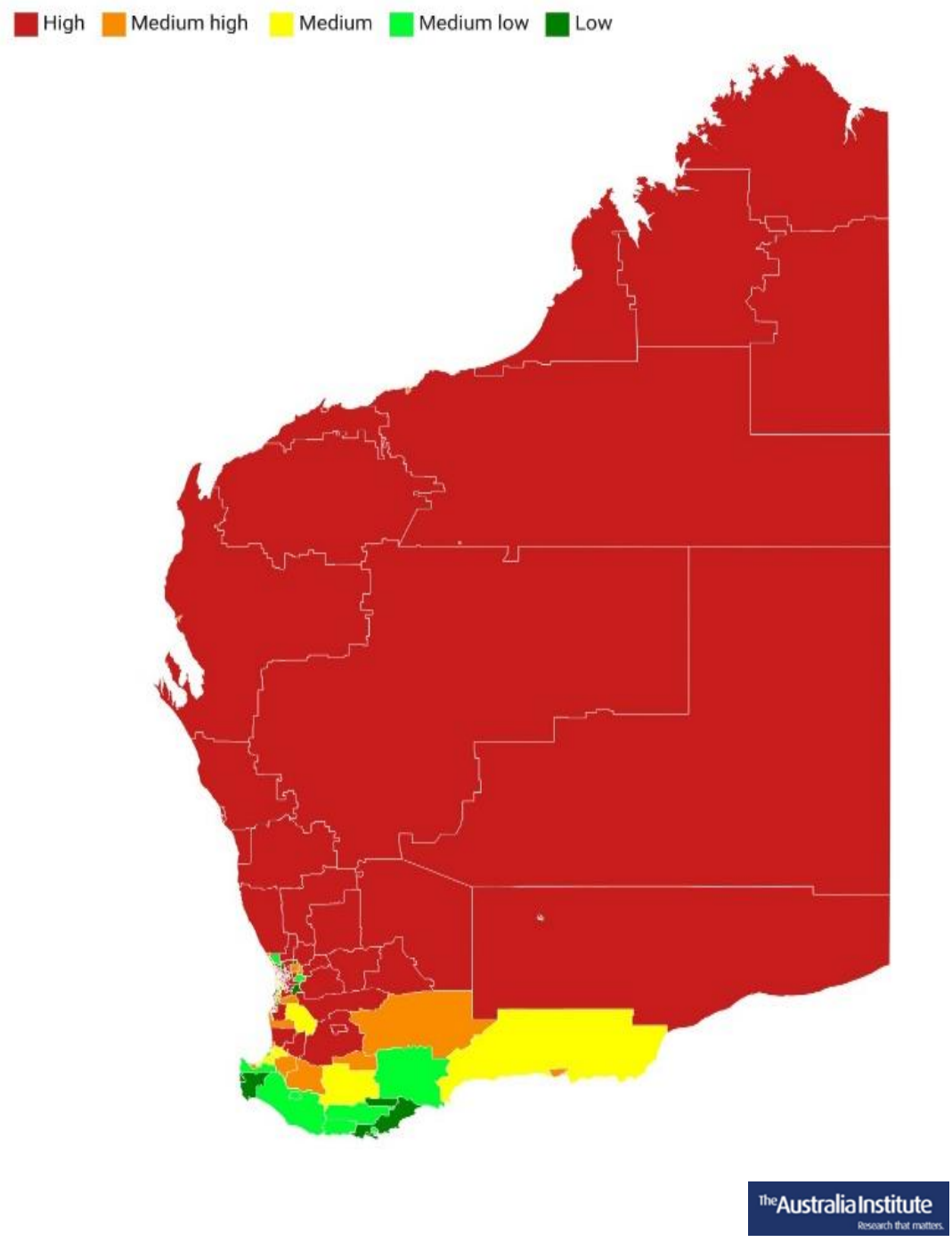
Table 8: Vulnerability to heat by location, Western Australia

	High	Medium high	Medium	Medium low	Low	Total
Western Australia						
Number of locations	138	68	18	12	29	265
Percentage of locations	52%	26%	7%	5%	11%	100%
Greater Perth						
Number of locations	99	53	10	3	20	185
Percentage of locations	54%	29%	5%	2%	11%	100%
The rest of Western Australia						
Number of locations	39	15	8	9	9	80
Percentage of locations	49%	19%	10%	11%	11%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 4 (below) shows that in Western Australia, the locations nearer the southern coast are less vulnerable to heat than those further north and inland.

Figure 4: Vulnerability to heat by location, Western Australia[27]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[27] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/HOlCW/4/

Table 9: Top 10 most heat vulnerable locations in Western Australia

Ranking	Location	Area
1	Derby - West Kimberley	Western Australia - Outback (North)
2	Northam	Western Australia - Wheat Belt
3	Broome	Western Australia - Outback (North)
4	Northampton - Mullewa - Greenough	Western Australia - Outback (South)
5	Morawa	Western Australia - Outback (South)
6	Geraldton	Western Australia - Outback (South)
7	Irwin	Western Australia - Outback (South)
8	York - Beverley	Western Australia - Wheat Belt
9	Gosnells	Perth - South East
10	Thornlie	Perth - South East

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Greater Perth and the rest of Western Australia

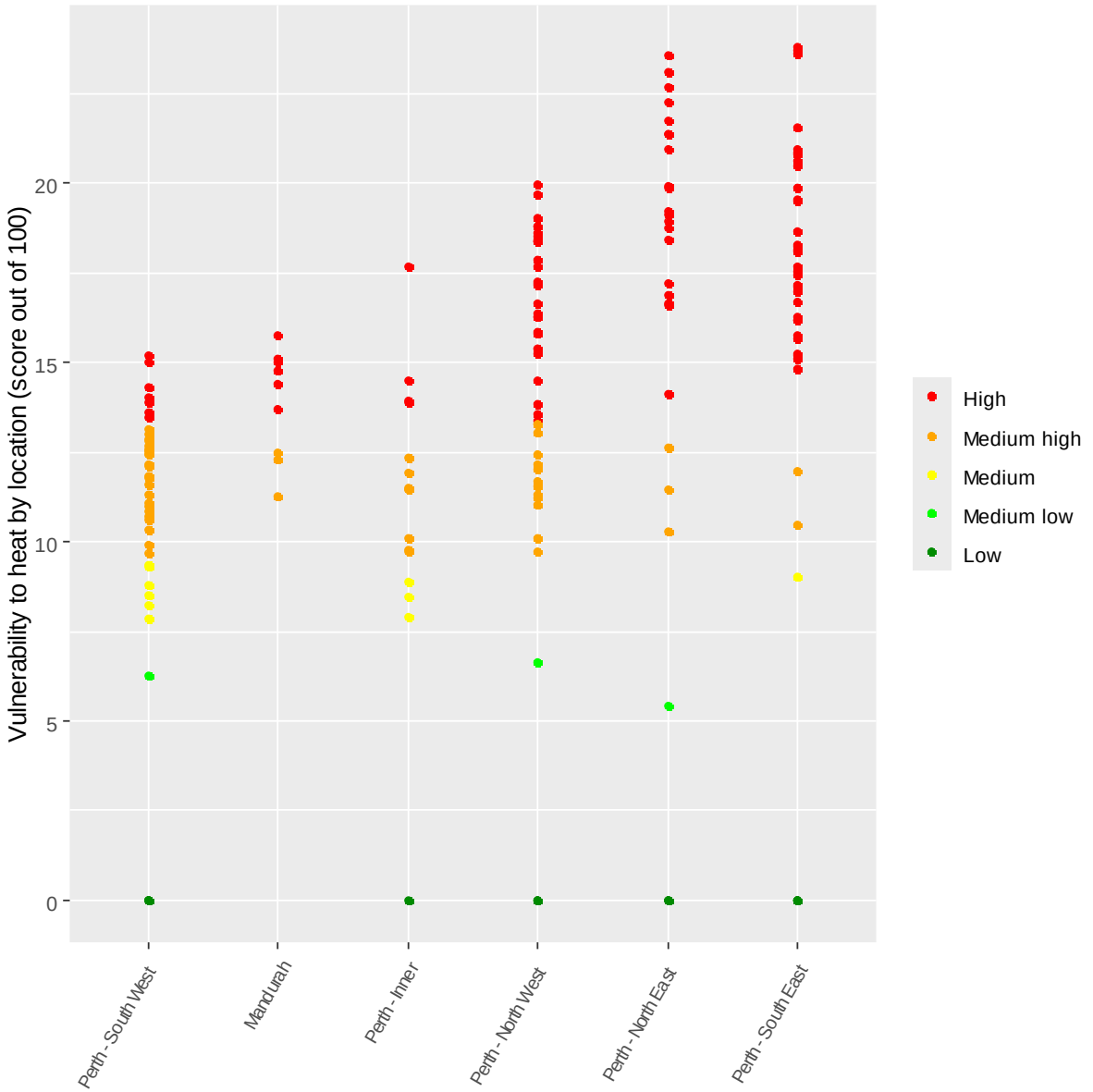
Table 8 shows that 54% of locations in Greater Perth are highly vulnerable to extreme heat, compared to 49% of the locations in the rest of Western Australia. The rest of Western Australia has eight out of the top 10 most vulnerable locations in the state. In addition, the average overall score of all locations in the rest of Western Australia is 13.9, compared to 13.3 in Greater Perth.

Greater Perth

Most locations in Greater Perth have a high or medium high level of vulnerability to extreme heat. Of the six areas that make up Greater Perth, Perth North East and Perth South East have the highest average heat vulnerability score (Chart 5). A look at the ABS's map for Perth South East and Perth South West shows that these areas are inland, and have sparse tree coverage and a large number of buildings. This may exacerbate the effects of extreme heat for vulnerable people. In contrast, Perth South West is the part of the city least vulnerable to extreme heat. It is near the coast, which helps keep temperatures down.[28]

[28]ABS (2024) *Data by region: search by map*, https://dbr.abs.gov.au/

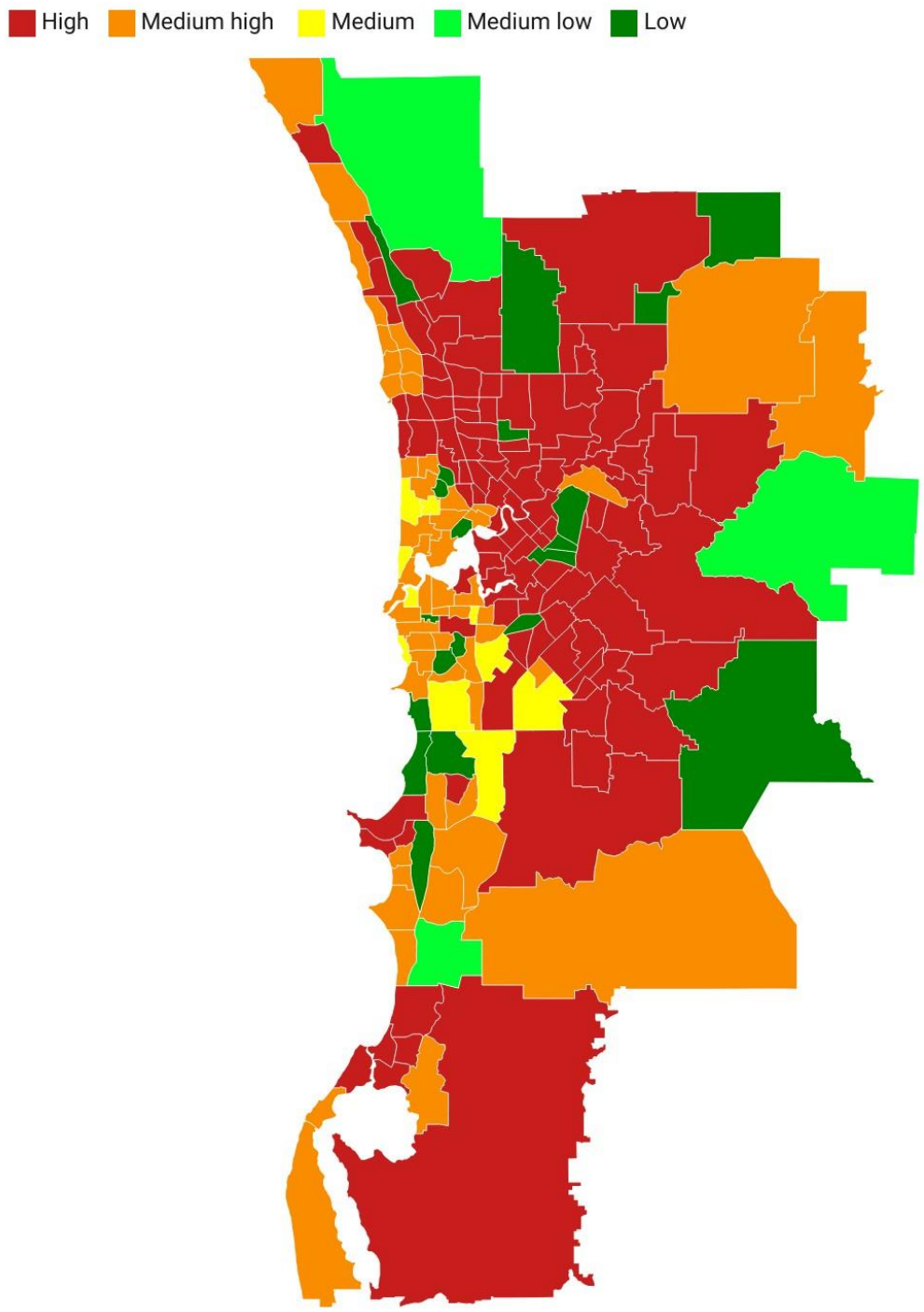
Chart 5: Vulnerability to heat by location, Greater Perth



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 5 shows that coastal locations in Greater Perth are less vulnerable to extreme heat than those further inland. Some inland locations, such as Malmalling-Reservoir, Ashendon-Lesley, and Avon Valley National Park are at a medium low or low level of vulnerability because, according to ABS data, they have less than 5 vulnerable people.

Figure 5: Vulnerability to heat by location, Greater Perth[29]



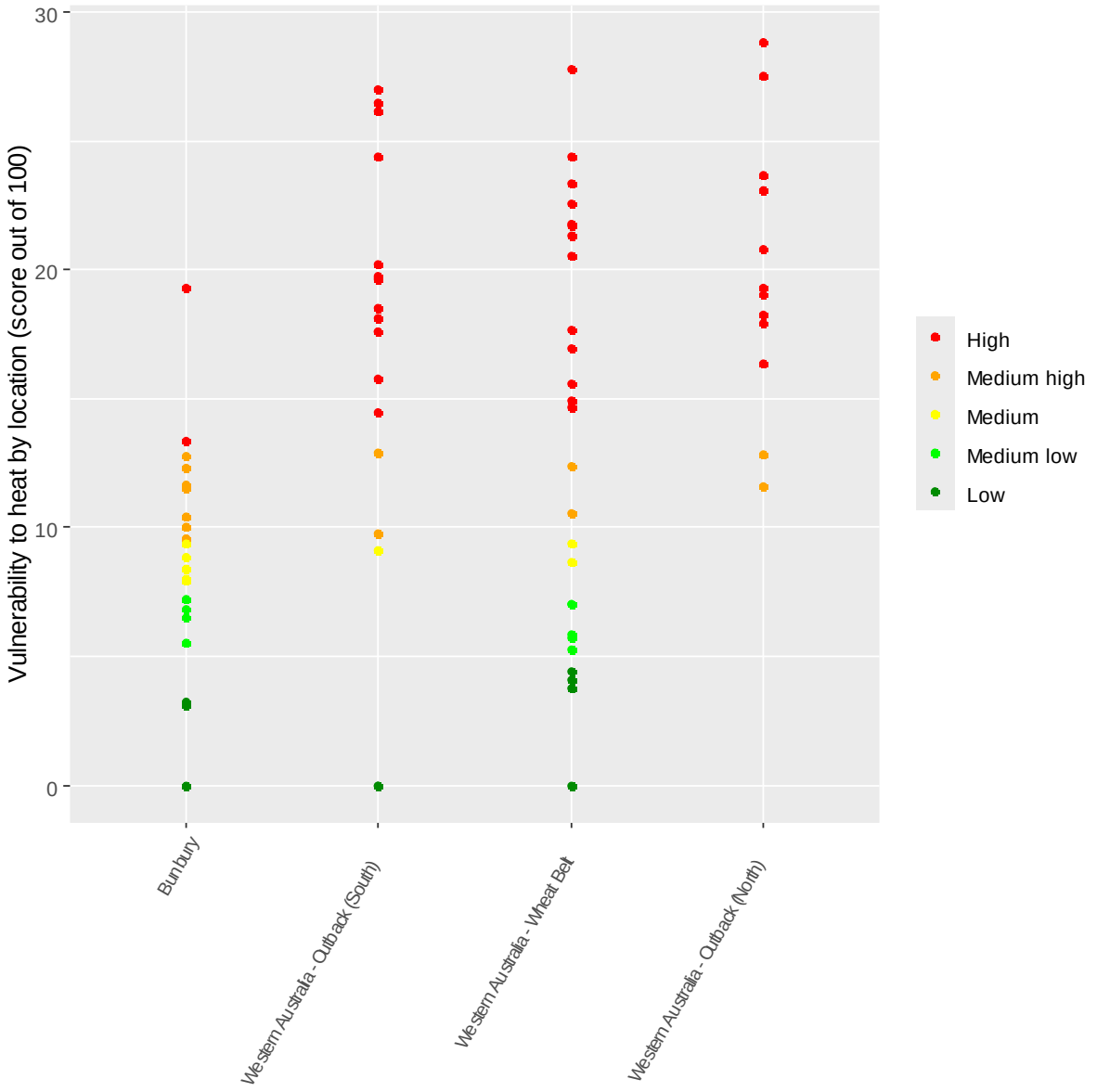
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[29] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/bk98E/4/

The rest of Western Australia

Out of four areas that make up the rest of Western Australia (i.e. outside of Perth) the most vulnerable is Outback (North) and (South) (Chart 6). Most locations in these two areas have a high or medium level of vulnerability to extreme heat. However, some locations in the Western Australia - Outback (South) area are categorised as low because they have a low concentration of vulnerable people (either at, or very close to, zero).

Chart 6 : Vulnerability to heat by location, the rest of Western Australia



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

NEW SOUTH WALES

Table 10 shows that of the 642 locations in New South Wales (NSW), 14% are highly vulnerable to extreme heat. Of the remainder, the vulnerability level is medium high for 21%, medium for 28%, medium low for 24%, and low for 13%.

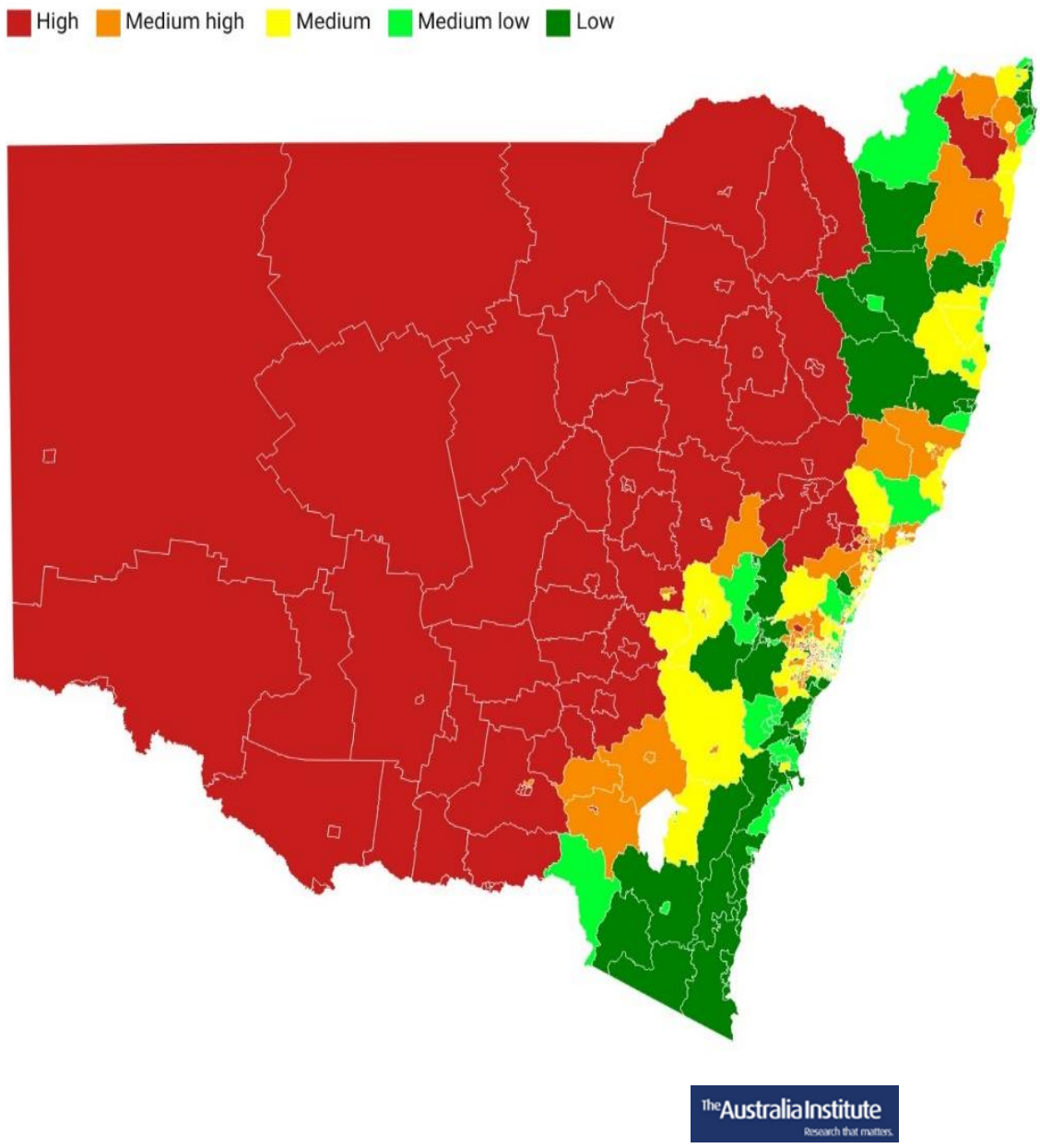
Table 10: Vulnerability to heat by location, NSW

	High	Medium high	Medium	Medium low	Low	Total
New South Wales						
Number of locations	91	133	179	155	84	642
Percentage of locations	14%	21%	28%	24%	13%	100%
Greater Sydney						
Number of locations	9	99	133	101	31	373
Percentage of locations	2%	27%	36%	27%	8%	100%
The rest of New South Wales						
Number of locations	82	34	46	54	52	268
Percentage of locations	31%	13%	17%	20%	19%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 6 shows that coastal locations are less vulnerable to extreme heat than inland locations.

Figure 6: Vulnerability to heat by location, NSW[30]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[30] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/gvFwp/4/

Table 11: Top 10 most heat vulnerable locations in NSW

Ranking	Location	Area
1	Broken Hill	Far West and Orana
2	Inverell Surrounds - West	New England and North West
3	Walgett - Lightning Ridge	Far West and Orana
4	Tocumwal - Finley - Jerilderie	Murray
5	Cowra	Central West
6	Forbes	Central West
7	Narrabri	New England and North West
8	Dubbo - South	Far West and Orana
9	Tamworth Surrounds	New England and North West
10	Griffith (NSW)	Riverina

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

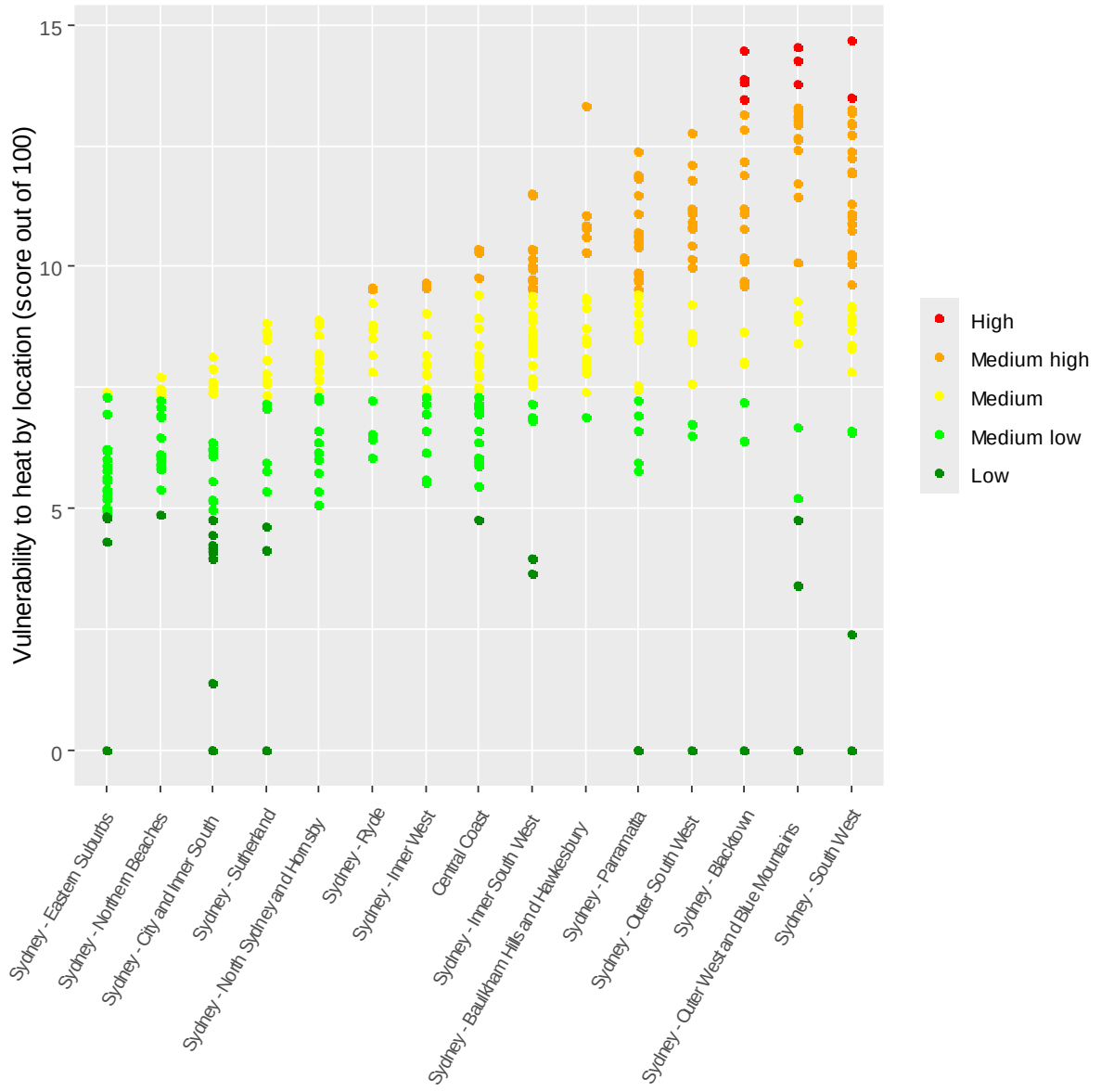
Greater Sydney and the rest of New South Wales

The rest of New South Wales is more vulnerable to extreme heat than Greater Sydney. Table 10 (above) shows that 31% of locations in the rest of New South Wales are highly vulnerable to heat, compared to only 2% in Greater Sydney. The top 10 most vulnerable locations in New South Wales are all outside of Greater Sydney (Table 11). The average overall score of all locations in the rest of New South Wales is 11, compared to 8.1 in Greater Sydney.

Greater Sydney

Of the 15 areas that make up Greater Sydney, only three include locations that are highly vulnerable to extreme heat (Chart 7 below). The least vulnerable areas are the Eastern Suburbs, and the Northern Beaches. The most vulnerable are the South West, the Outer West and Blue Mountains, and Blacktown. A look at the ABS's map shows that the least vulnerable areas are along the coast, while those most vulnerable to heat are inland.

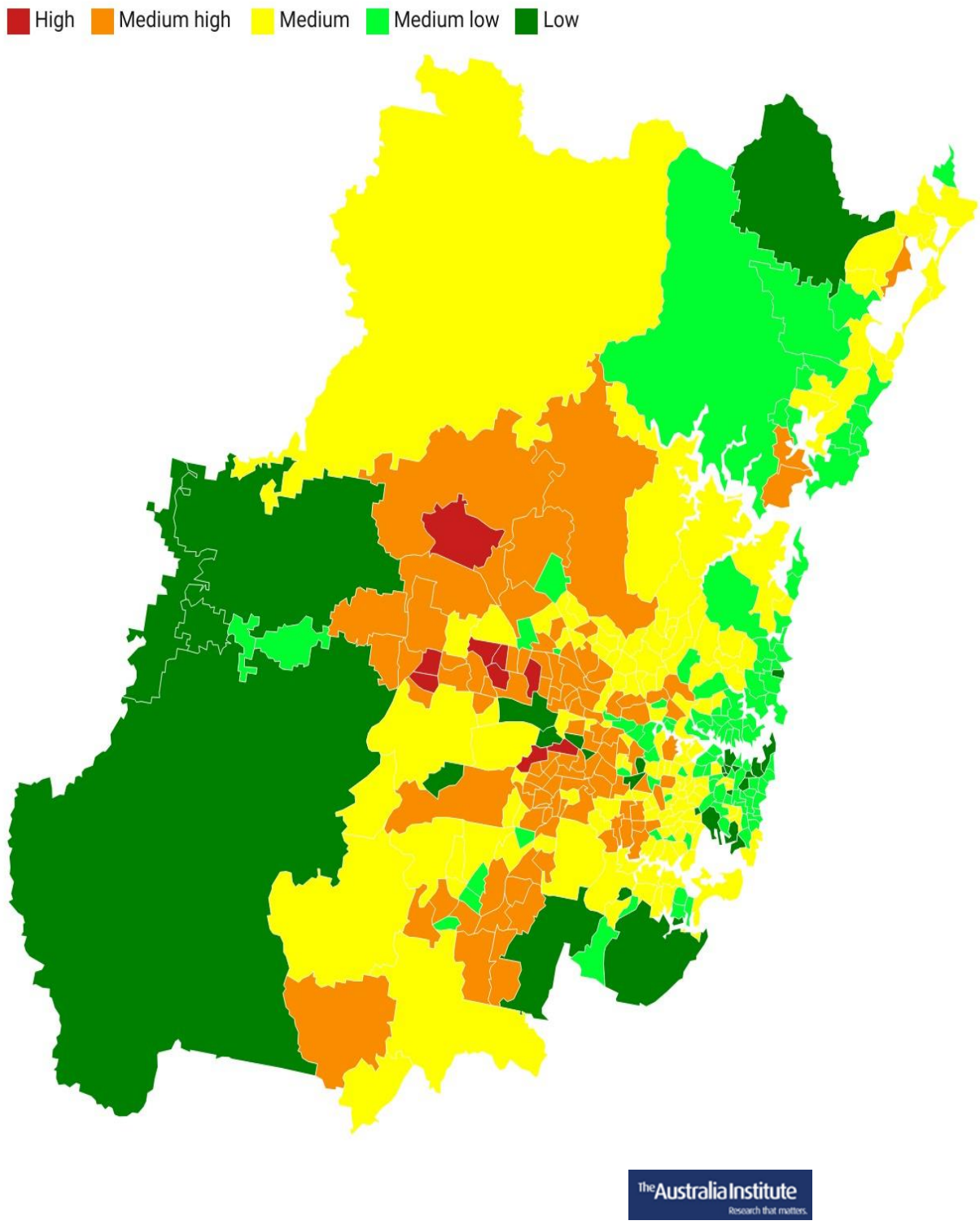
Chart 7: Vulnerability to heat by location, Greater Sydney



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Locations nearer the coast are less vulnerable to heat than inland locations (Figure 7). Because of the way our method takes population density into account, some inland locations with low populations have been classified as low. Within Greater Sydney, coastal areas tend to have cooler temperatures and wealthier residents, whereas inland areas tend to have hotter temperatures and more vulnerable residents. This means that vulnerability to heat generally increases with distance from the coast.

Figure 7: Vulnerability to heat by location, Greater Sydney[31]



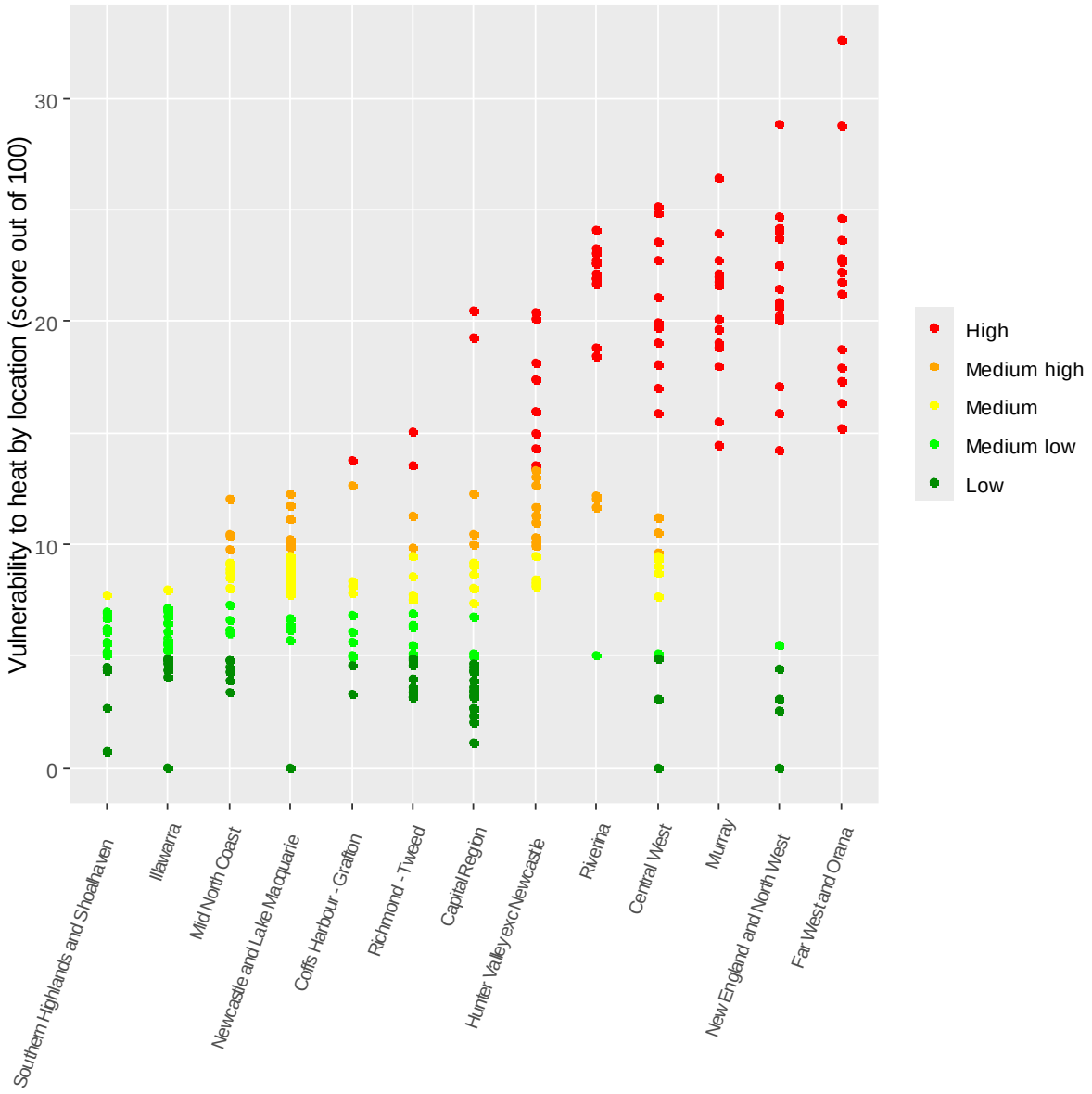
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[31] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/AFcEw/7/

The rest of New South Wales

Chart 8 shows that the most vulnerable areas in the rest of New South Wales are Far West and Orana, New England and North west, and Murray. A look at the ABS's map for these areas shows that these areas are inland and have sparse tree coverage, which may exacerbate the effects of extreme heat for vulnerable people. In contrast, the least vulnerable areas are the Southern Highlands and Shoalhaven, Illawarra, the Mid North Coast, Newcastle and Lake Macquarie. These areas are near the coast and have better tree coverage, which helps keep temperatures down.[32]

Chart 8: Vulnerability to heat by location, the rest of NSW



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

[32]ABS (2024) *Data by region: search by map*, https://dbr.abs.gov.au/

QUEENSLAND

Table 12 shows that of the 545 locations in Queensland, 12% are highly vulnerable to extreme heat. Of the remainder, the vulnerability level is medium high for 10%, medium for 13%, medium low for 32%, and low for 33%.

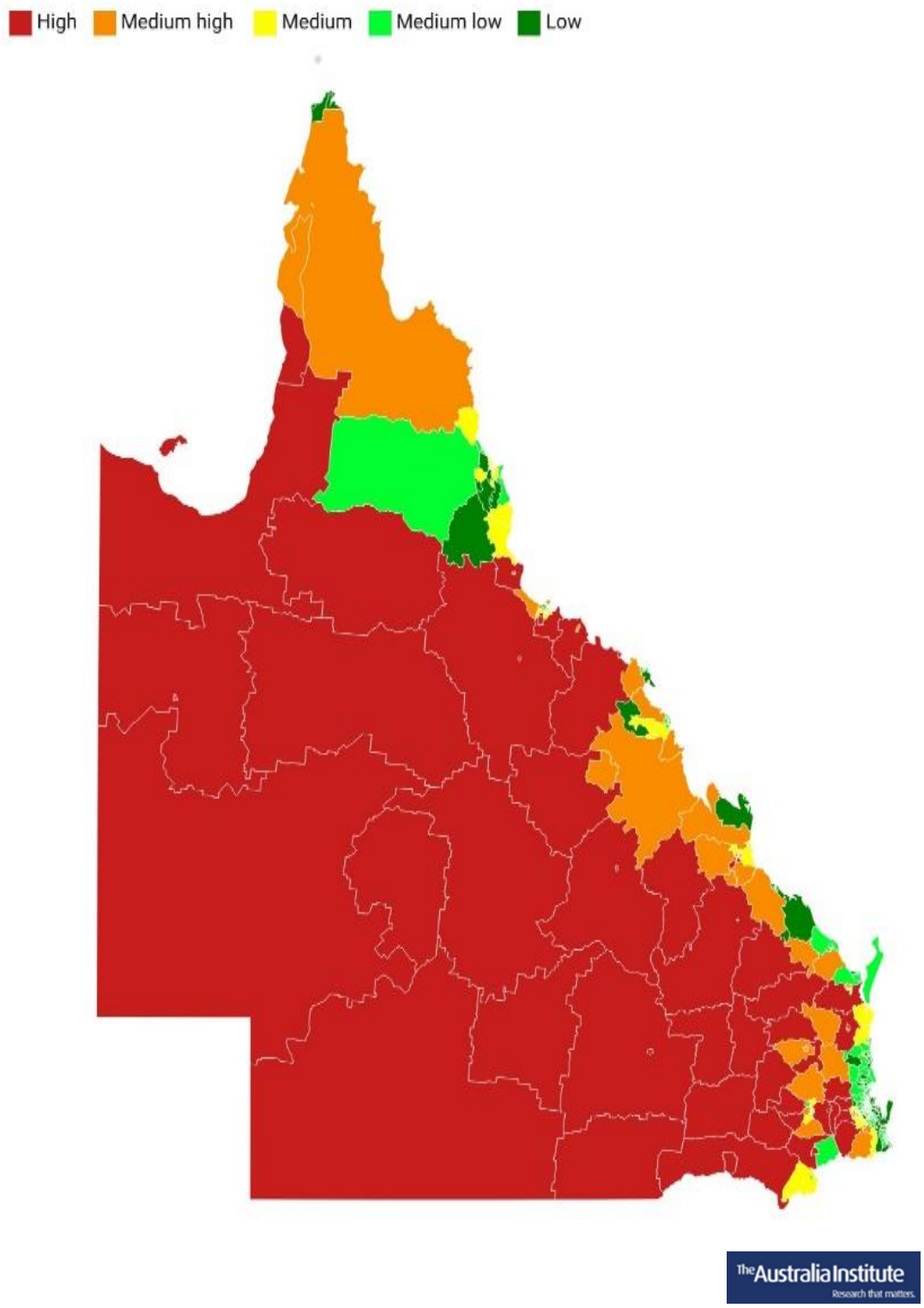
Table 12: Vulnerability to heat by location, Queensland

	High	Medium high	Medium	Medium low	Low	Total
Queensland						
Number of locations	63	56	71	174	181	545
Percentage of locations	12%	10%	13%	32%	33%	100%
Greater Brisbane						
Number of locations	9	13	17	104	103	246
Percentage of locations	4%	5%	7%	42%	42%	100%
The rest of Queensland						
Number of locations	54	43	54	70	78	299
Percentage of locations	18%	14%	18%	23%	26%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 8 shows that coastal locations are less vulnerable to heat than inland locations.

Figure 8: Vulnerability to heat by location, Queensland[33]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[33] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/kgHd6/5/

Table 13: Top 10 most heat vulnerable locations in Queensland

Ranking	Location	Area
1	Mount Isa	Queensland - Outback
2	Charters Towers	Townsville
3	Barcaldine - Blackall	Queensland - Outback
4	Central Highlands - West	Central Queensland
5	Roma Surrounds	Darling Downs - Maranoa
6	Emerald	Central Queensland
7	Inglewood - Waggamba	Darling Downs - Maranoa
8	Tara	Darling Downs - Maranoa
9	Wambo	Darling Downs - Maranoa
10	Banana	Central Queensland

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Greater Brisbane and the rest of Queensland

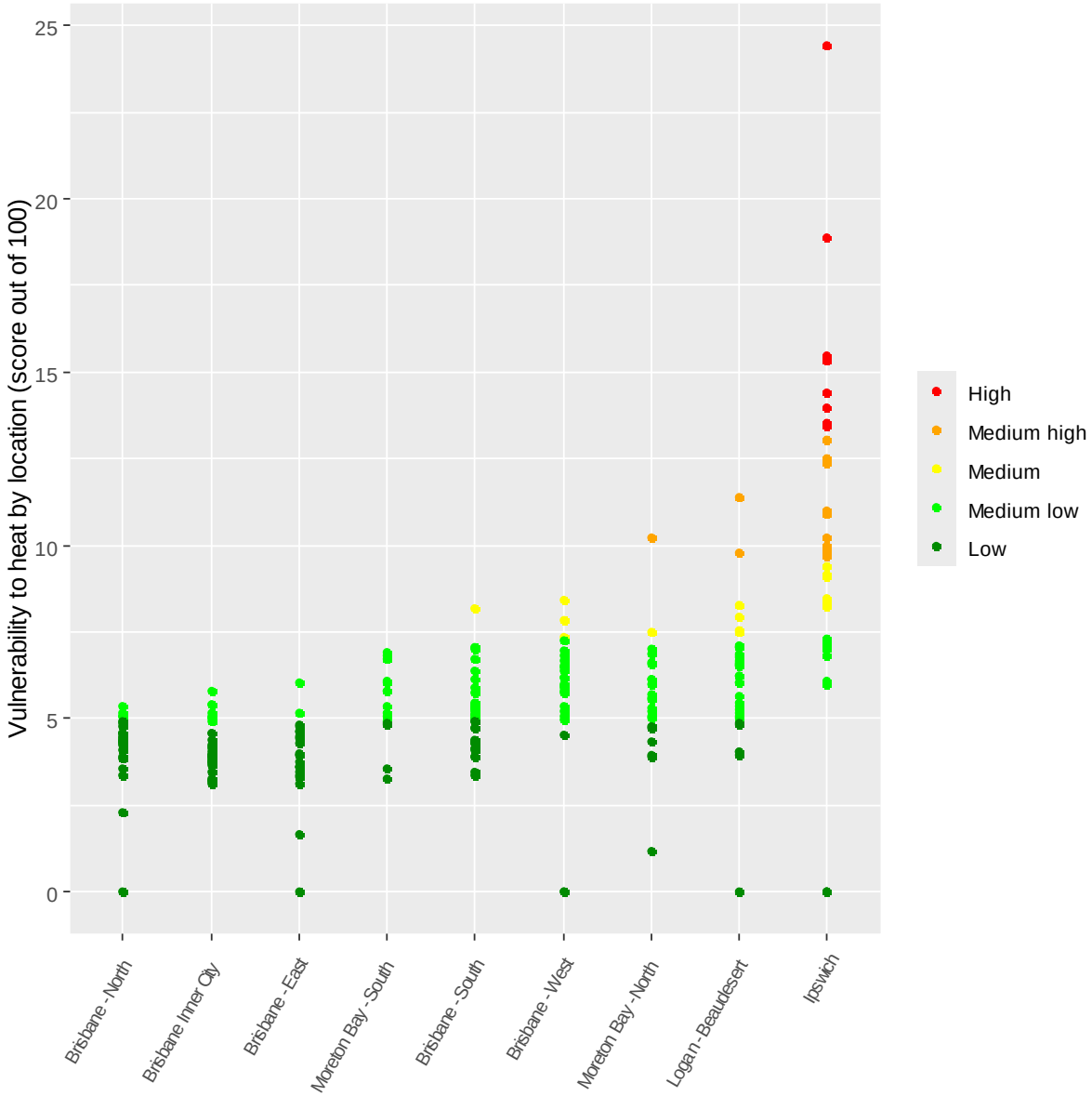
The rest of Queensland is more vulnerable to extreme heat than Greater Brisbane. In the rest of Queensland, 18% of locations are highly vulnerable to extreme heat, compared to only 4% in Greater Brisbane (Table 12). The top 10 most vulnerable locations in Queensland are all in the rest of Queensland (Table 13). The average overall score of all locations in the rest of Queensland is 9.1, compared to 5.8 in Greater Brisbane.

Greater Brisbane

Among the nine areas within Greater Brisbane, Ipswich is most vulnerable to extreme heat (Chart 9). A look at the ABS's map for Ipswich shows that this area is inland and has sparse tree coverage, which may exacerbate the effects of extreme heat for vulnerable people. In contrast the least vulnerable areas – Brisbane East, Brisbane North, Brisbane Inner City, and Moreton Bay South – are near the coast and have better tree coverage, which helps keep temperatures down.[34]

[34]ABS (2024) *Data by region: search by map*, https://dbr.abs.gov.au/

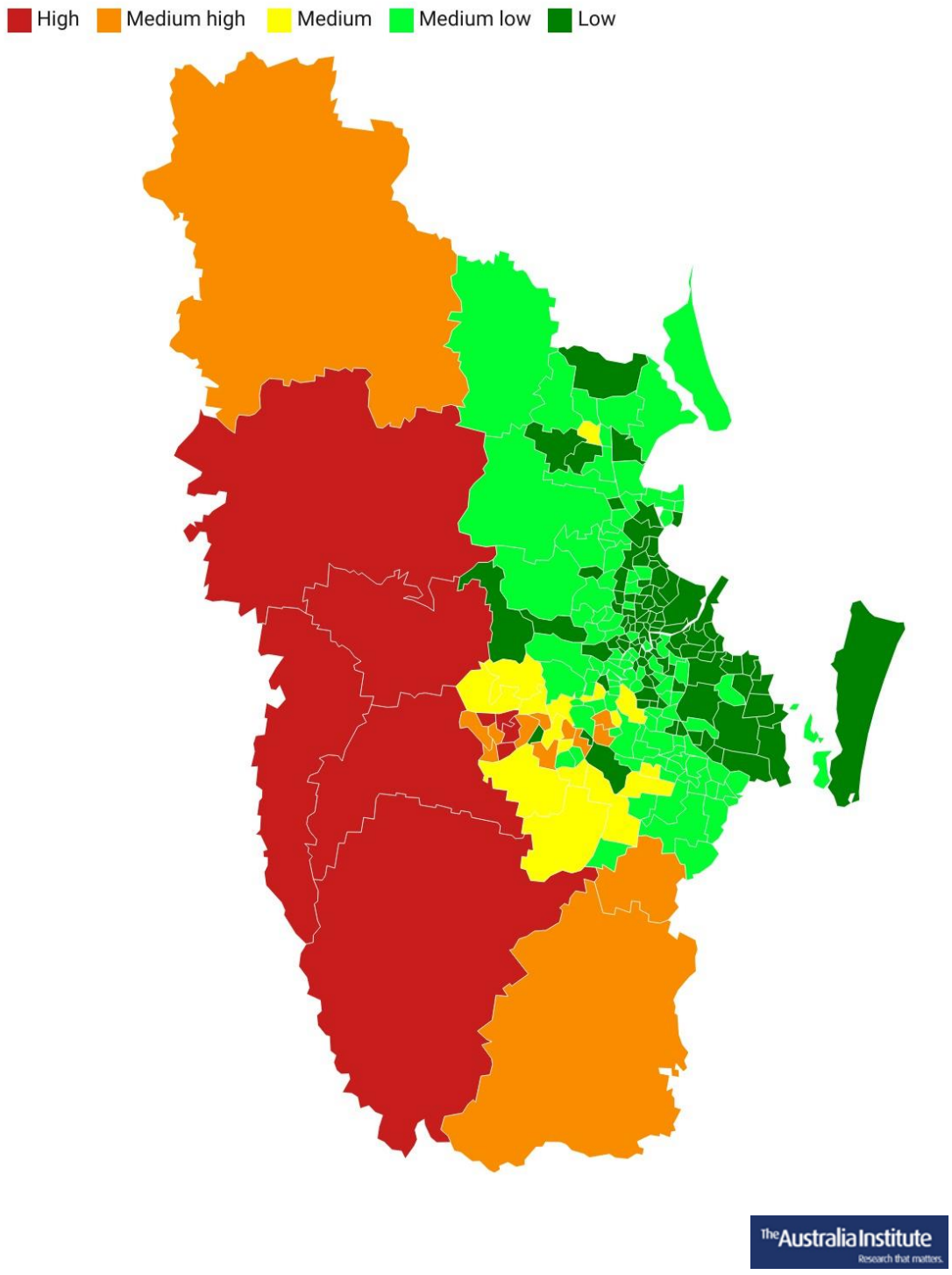
Chart 9: Vulnerability to heat by location, Greater Brisbane



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 9 shows that coastal locations in Greater Brisbane are far less vulnerable to extreme heat compared to those located further inland.

Figure 9: Vulnerability to heat by location, Greater Brisbane[35]



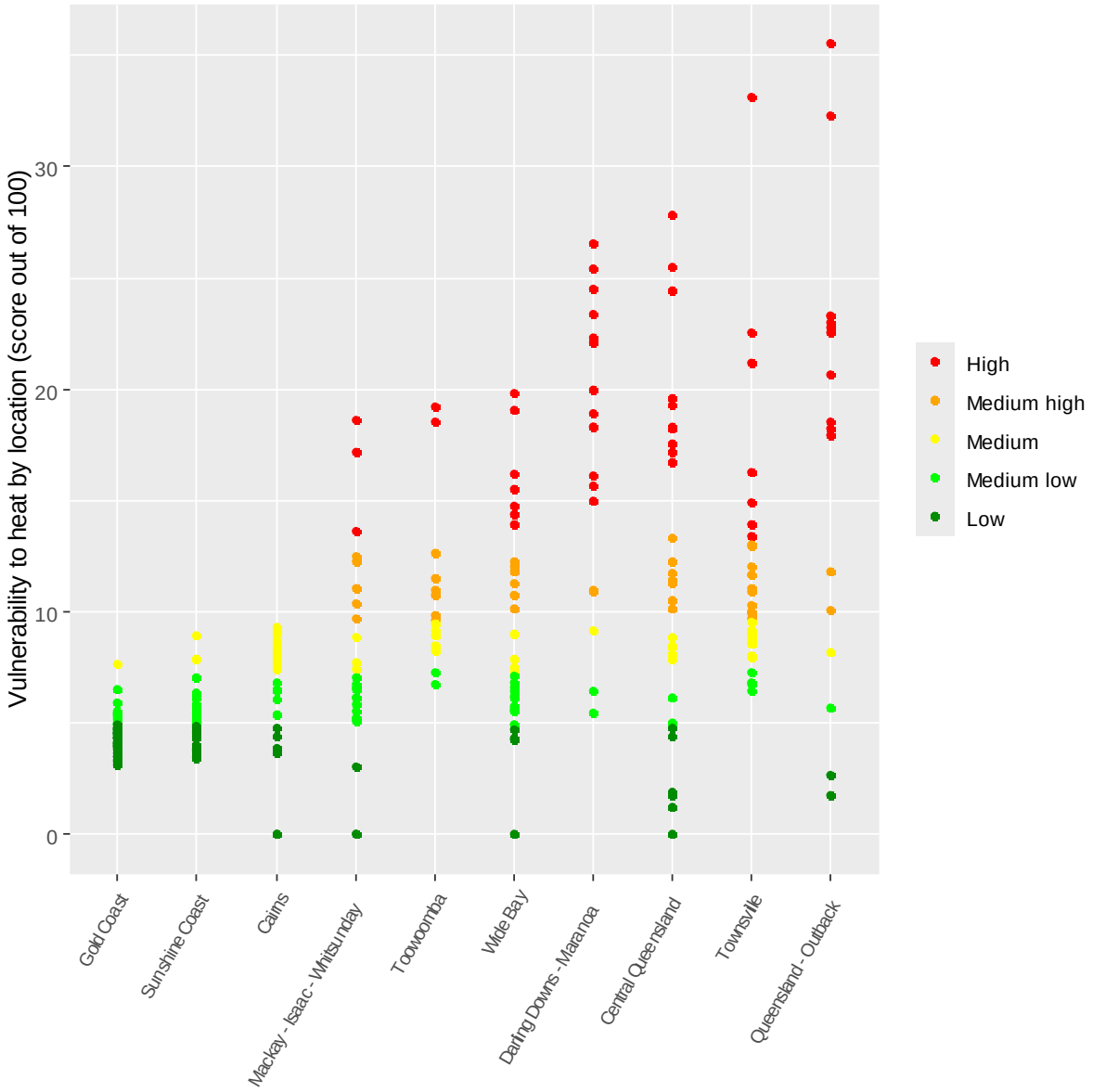
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[35] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/NsFKN/5/

The rest of Queensland

Within the rest of Queensland, the areas most vulnerable to extreme heat are the Outback, Townsville, Central Queensland, and Darling Downs – Maranoa (Chart 10). However, vulnerability is not distributed evenly because these areas are so large that they contain both coastal locations that have a low vulnerability to heat, and inland locations that are highly vulnerable to heat. In contrast, the least vulnerable locations are the Gold Coast, the Sunshine Coast, and Cairns.

Chart 10: Vulnerability to heat by location, the rest of Queensland



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

VICTORIA

Of the 522 locations in Victoria, 9% are highly vulnerable to heat. Of the remaining locations, the vulnerability level is medium high for 34%, medium for 39%, medium low for 14%, and low for 4% (Table 14).

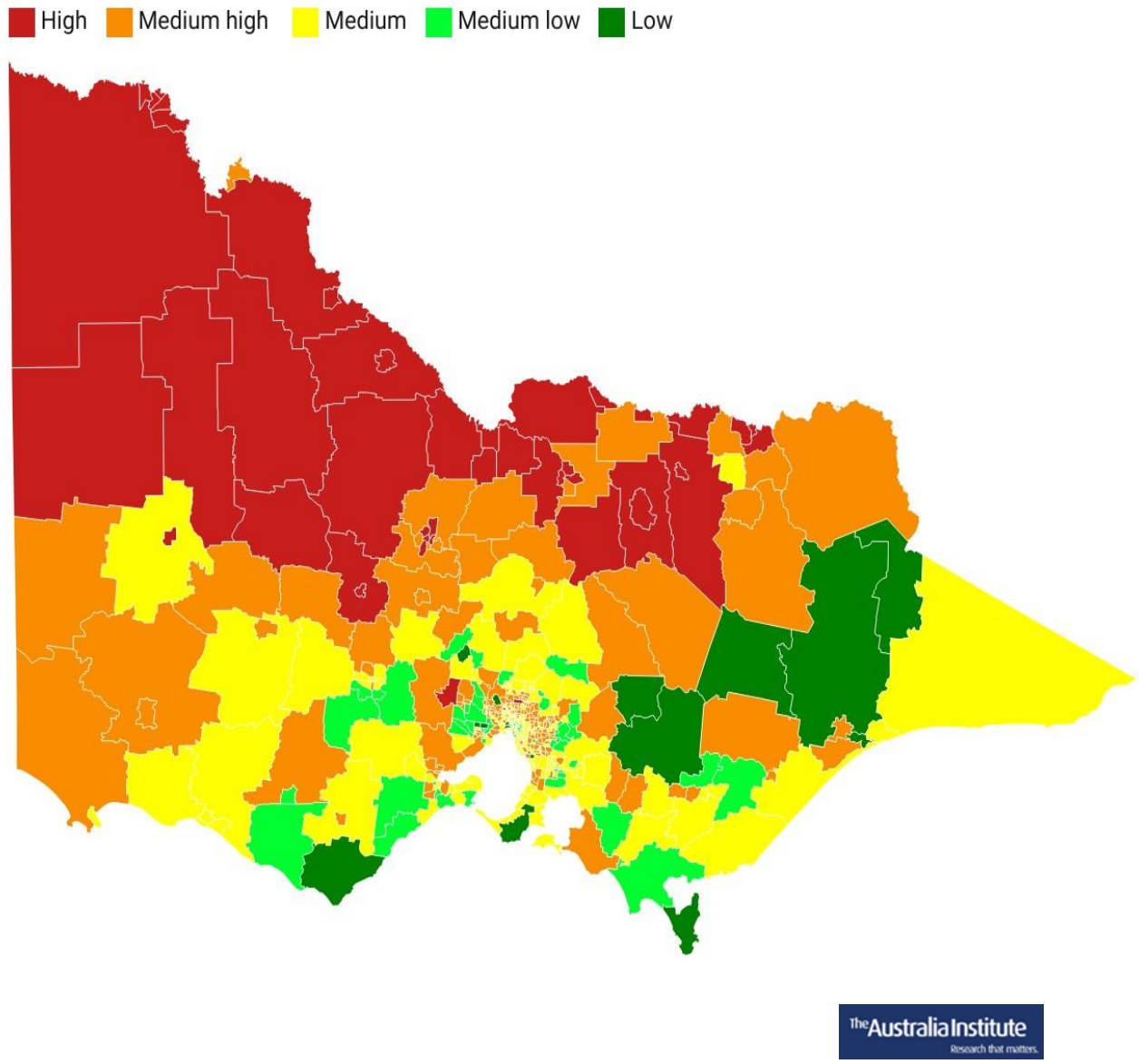
Table 14: Vulnerability to heat by location, Victoria

	High	Medium high	Medium	Medium low	Low	Total
Victoria						
Number of locations	45	180	201	74	22	522
Percentage of locations	9%	34%	39%	14%	4%	100%
Greater Melbourne						
Number of locations	2	127	162	57	13	361
Percentage of locations	1%	35%	45%	16%	4%	100%
The rest of Victoria						
Number of locations	43	53	39	17	9	161
Percentage of locations	27%	33%	24%	11%	6%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 10 shows that coastal locations in Victoria are less vulnerable than inland locations.

Figure 10: Vulnerability to heat by location, Victoria[36]



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[36] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/RMEl9/4/

Table 15: Top 10 most heat vulnerable locations in Victoria

Ranking	Location	Area
1	Mildura - North	North West
2	Mildura - South	North West
3	Wangaratta	Hume
4	Numurkah	Shepparton
5	Yarrawonga	Shepparton
6	Echuca	Shepparton
7	West Wodonga	Hume
8	Gannawarra	North West
9	Swan Hill	North West
10	Cobram	Shepparton

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

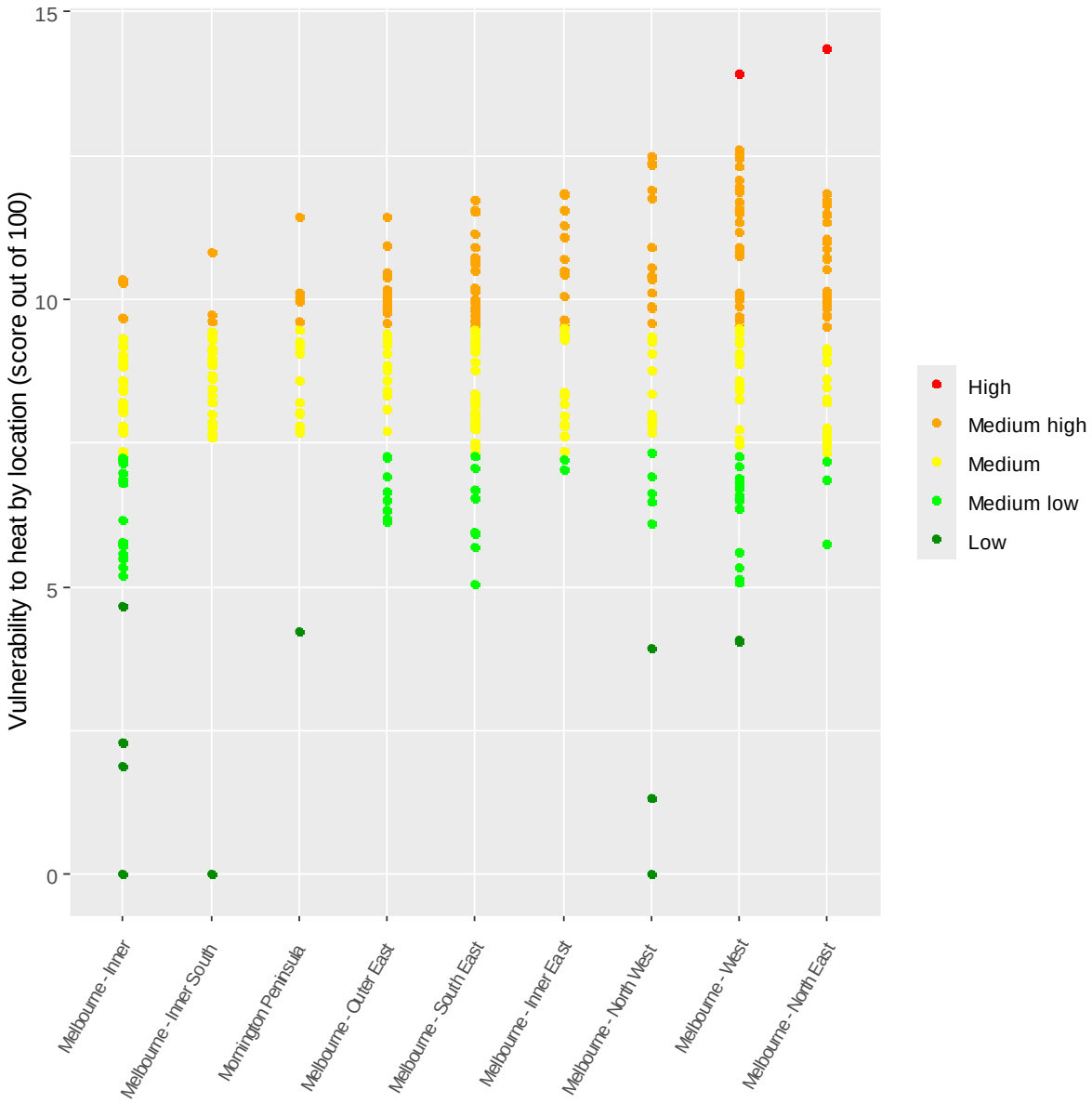
Greater Melbourne and the rest of Victoria

The rest of Victoria is more vulnerable to heat than Greater Melbourne. As Table 14 (above) shows, 27% of locations in the rest of Victoria are highly vulnerable to extreme heat, compared to only 1% of those in Greater Melbourne. The top 10 most vulnerable locations in Victoria are all in the rest of Victoria (Table 15). The average overall score of all locations in the rest of Victoria is 11.7, compared to 8.7 in Greater Melbourne.

Greater Melbourne

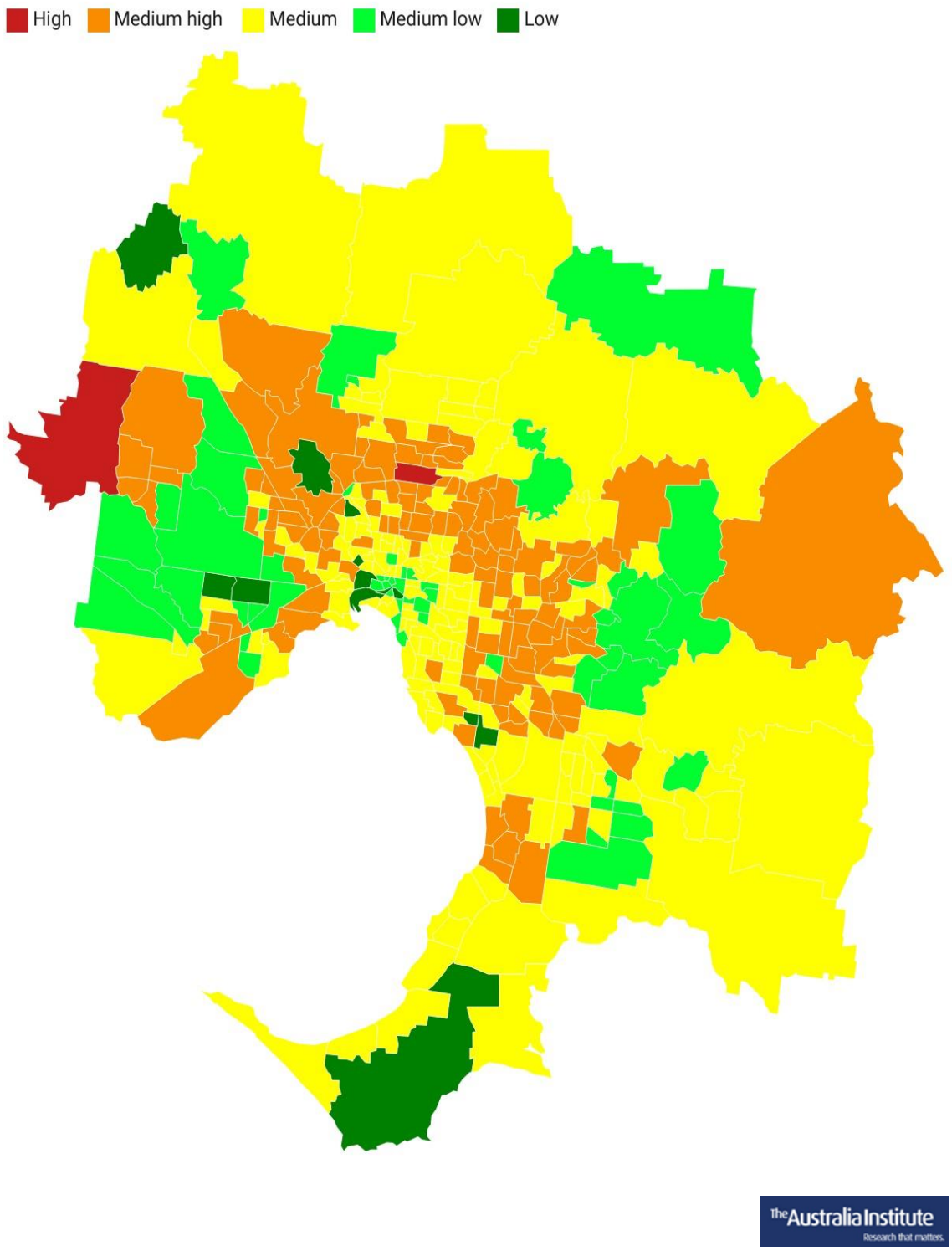
Only 1% of locations in Greater Melbourne are highly vulnerable to heat, and these are limited to the Melbourne North East and Melbourne West areas (Chart 11).

Chart 11: Vulnerability to heat by location, Greater Melbourne



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Figure 11:Vulnerability to heat by location, Greater Melbourne[37]



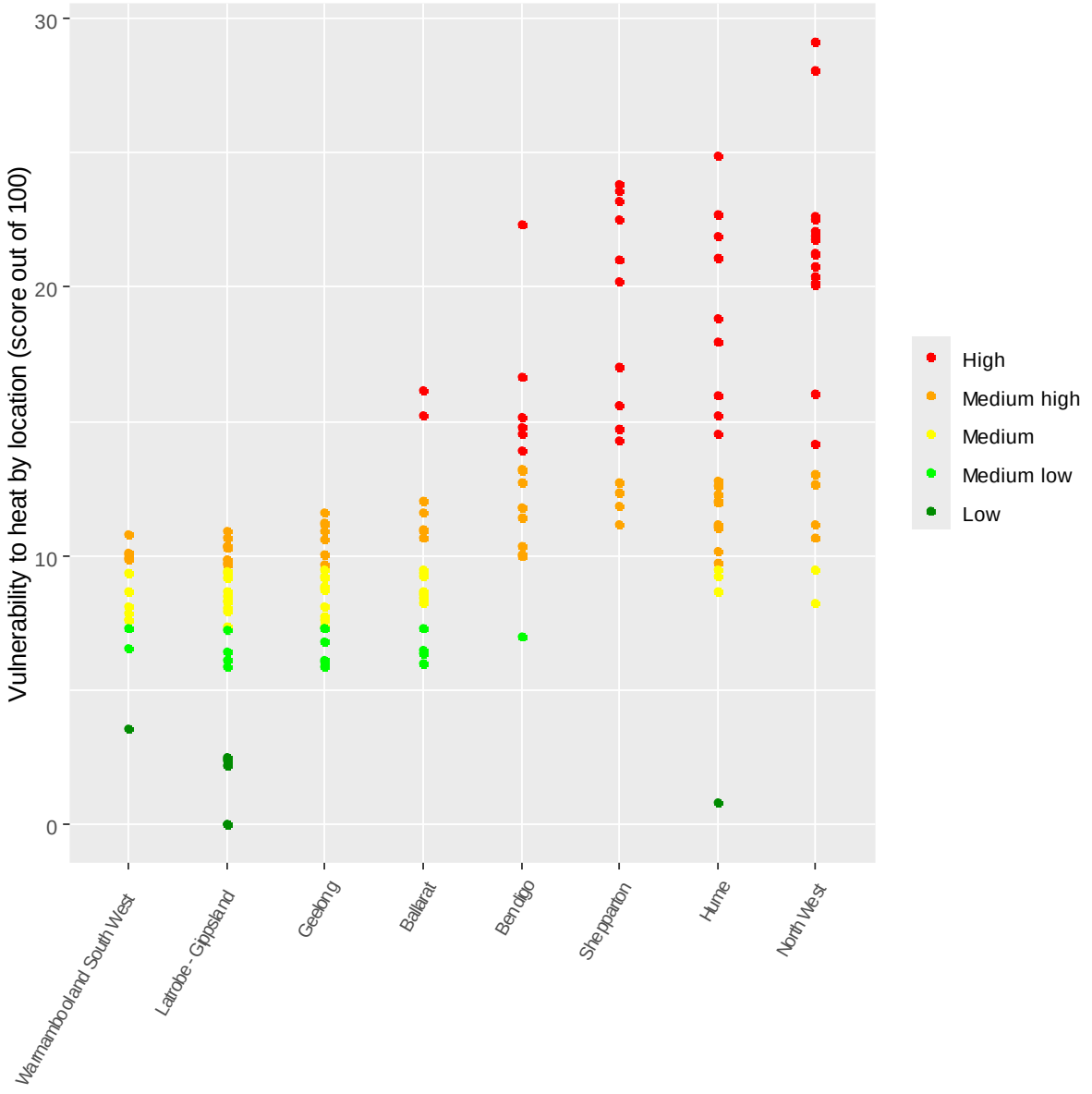
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018) and map data: ABS (2021).

[37] Each location (SA2) on this map can be identified at the following link: https://datawrapper.dwcdn.net/7SFME/4/

The rest of Victoria

Chart 12 shows that most of the highly vulnerable locations in Regional Victoria are in the North West, Hume, and Shepparton areas, all of which are inland. The least vulnerable areas closer to the coast, including Geelong, Latrobe – Gippsland, and Warrnambool and South West.

Chart 12: Vulnerability to heat by location, the rest of Victoria



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

AUSTRALIAN CAPITAL TERRITORY

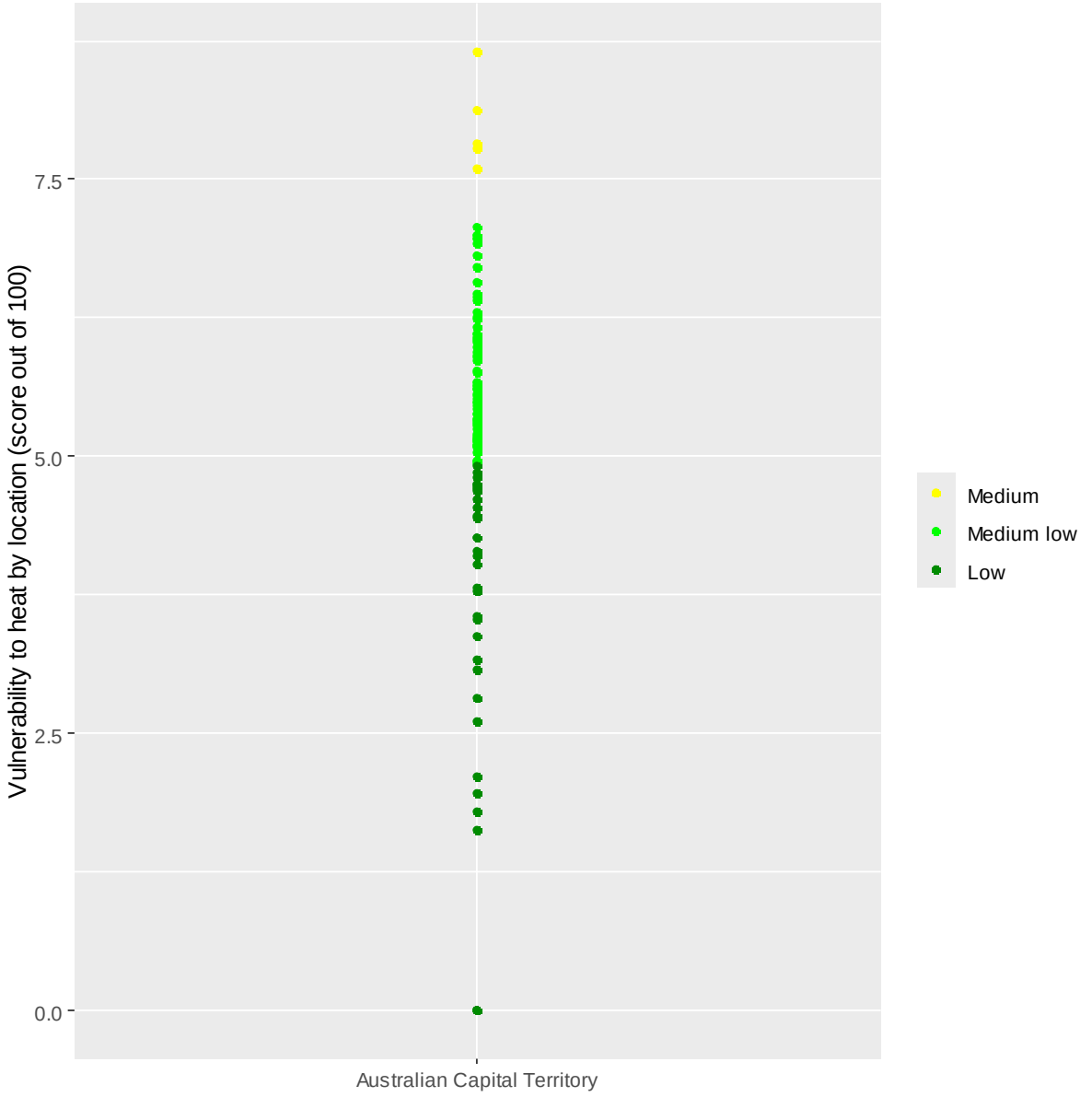
Nearly all locations in the Australian Capital Territory (ACT) (96%) have a medium low or low level of vulnerability to extreme heat. No locations in the ACT are highly vulnerable, and just five have a medium level of vulnerability (Table 16 and Chart 13). The ACT's generally low level of vulnerability is because, compared to the rest of Australia, it has a lower number of vulnerable people, and relatively fewer projected days over 35°C.

Table 16: Vulnerability to heat by location, ACT

	High	Medium high	Medium	Medium low	Low	Total
Number of locations	0	0	5	71	58	134
Percentage of locations	0%	0%	4%	53%	43%	100%

Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

Chart 13: Vulnerability to heat by location, ACT



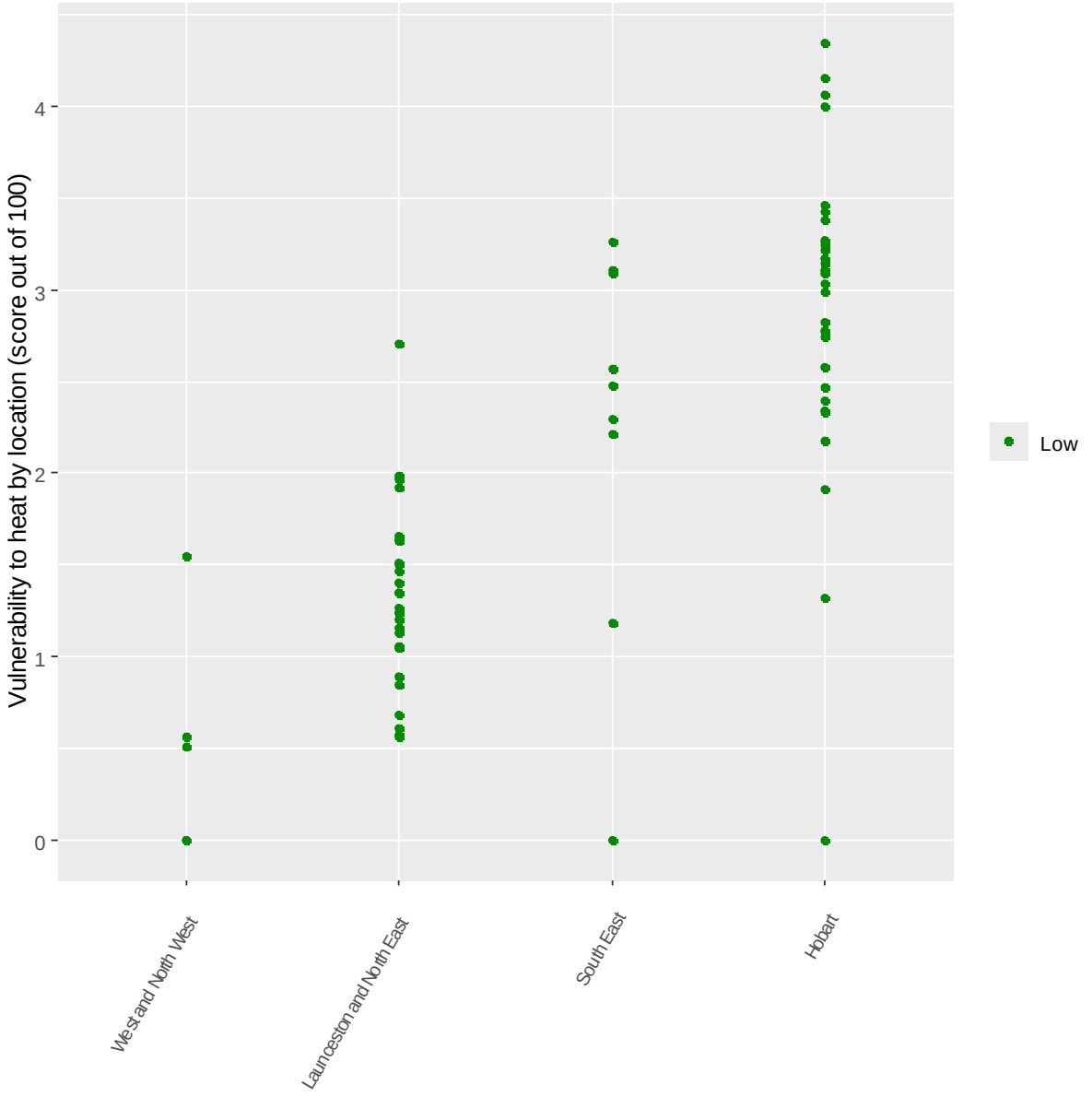
Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

TASMANIA

The threat posed by extreme heat is low across Tasmania because the projected number of days above 35°C is low (Chart 14). This is not to say that Tasmania is unaffected by heat. Even this southern-most state can experience extreme heat, which can still affect vulnerable

populations.[38] However, in contrast to the rest of Australia, the leading weather-related cause of hospitalisation and death in Tasmania is not extreme heat but extreme cold.[39]

Chart 14: Vulnerability to heat by location, Tasmania



Source: Calculations by author based on data from the ABS (2021) and CSIRO (2018).

[38] Johnston (2022) *Heatwaves in Tasmania? Stop laughing, here's what you need to know*, https://www.abc.net.au/news/2022-11-29/heatwaves-in-tasmania-here-is-what-you-need-to-know/101568360

[39] AIHW (2023) *Let's talk about the weather: Injuries related to extreme weather.*

Conclusion

As this report has shown, extreme heat will affect much of Australia. Wealthier, coastal areas in major cities are generally less vulnerable to extreme heat than areas away from the coast. This is because outer suburbs and regional areas generally have higher concentrations of vulnerable people than wealthier coastal areas, and because they will get hotter than coastal areas as the effects of climate change intensify.

While all vulnerable individuals require assistance to mitigate heat-related health risks, additional relief should be targeted at areas that have both higher concentrations of vulnerable populations and a greater likelihood of extreme heat. People with limited financial resources, especially those dependent on income support payments, often struggle to afford protection from intense heat. This means that climate change disproportionately impacts low-income earners, especially those who are elderly and/or live with a medical condition. Although not captured in our analysis, babies and small children are also more vulnerable to the deleterious effects of extreme heat,[40] while children and young people are more likely to present to emergency departments with suicidal throughs or behaviours in hot weather.[41] In recognition of the health harms caused by global heating, Doctors for the Environment Australia have called for the use of fossil fuels to be phased out.[42]

In the northern-hemisphere summer of 2024, Arizona was one of several parts of the United States that grappled with the effects of extreme heat. In response, some legal advocates began to push for oil companies to be held accountable for the deaths caused by climate-induced heatwaves.[43] In Australia, Governments at the state, territory and Commonwealth level can act now to prevent the hospitalisations, illness, and death that extreme heat will cause. The only way to reduce the threat that extreme heat poses to Australia in the future is to transition away from the use of fossil fuels now. The subsidies given to the fossil fuel industries, which exacerbate the effects of climate change, could instead be used for building resilient support systems for vulnerable people. This would better protect Australians from extreme heat - now and in the future.

[40] Sydney Children's Hospitals Network (2024) *Summer Heat Safety*, https://www.schn.health.nsw.gov.au/kids-health-hub/kids-seasonal-health-alerts/summer-heat-safety-kids

[41] Dey et al. (2024) 'Youth suicidality risk relative to ambient temperature and heatwaves across climate zones: A time series analysis of emergency department presentations in New South Wales, Australia', *Australian and New Zealand Journal of Psychiatry*, https://journals.sagepub.com/doi/10.1177/00048674241290449

[42] Doctors for the Environment Australia (2024) *Doctors for the Environment Australia is the leading medical voice on health and climate*, https://www.dea.org.au/

[43] Noor (2024) *Lawyers could charge big oil with homicide after 2023 Arizona heatwave*, https://www.theguardian.com/us-news/article/2024/jun/26/arizona-heatwave-big-oil-lawsuit