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Type of article		Perspective
Title	The 2020 special report of the <i>MJA-Lancet</i> Countdown on health and climate change: lessons learnt from Australia's 'Black Summer'	

Summary	
Summary word count	285

- The *MJA-Lancet* Countdown on health and climate change was established in 2017, produced its first Australian national assessment in 2018 and its first annual update in 2019. It examines indicators across five broad domains: climate change impacts, exposures and vulnerability; adaptation, planning and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement.
- In the wake of the unprecedented and catastrophic 2019/20 Australian bushfire season, in this special report we present the 2020 update, with a focus on the relationship between health, climate change, and bushfires, highlighting indicators that explore these linkages.
- In an environment of continuing increases in summer maximum temperatures and heatwave intensity, substantial increases in both fire risk and population exposure to bushfires is impacting Australia's health and economy. As a result of the 'Black Summer' bushfires, the monthly airborne particulate matter (PM_{2.5}) concentration in NSW was the highest of any month in any state or territory over the period 2000-2019 at almost 30 µg/m³, and insured economic losses were \$2.2 billion.
- We also find growing awareness of and engagement with the links between health and climate change, with a 50% increase in scientific publications and a doubling of newspaper articles on the topic in Australia in 2019. However, despite clear and present need, Australia still lacks a nation-wide adaptation plan for health. As Australia recovers from the compounded effects of the bushfires and the coronavirus disease (COVID-19) pandemic, the health profession has a pivotal role to play. It is uniquely suited to integrate the response to these short-term threats with the longer-term public health implications of climate change, and to argue for the economic recovery from COVID-19 to align with and strengthen Australia's commitments under the Paris Agreement.

Text	
Text word count	3409

Introduction

The effects of climate change are felt by populations around the world and across income groups, with the health of the Australian public uniquely at risk.^{1,2} In response to growing and concerning evidence, leading health bodies, including the Australian Nursing and Midwifery Federation, the Australian Medical Association, the Australian Nursing College, and the majority of the medical colleges, have all declared climate change a health emergency – urging an accelerated response to reducing emissions and preparing health systems.³⁻¹²

Compounding the longer-term effects of climate change, Australia has faced two acute national emergencies over the last 12 months, in the form of the unprecedented and catastrophic 2019/20 Australian bushfire season, and the global coronavirus disease (COVID-19) pandemic. In the first instance, compelling attribution studies provide direct links between climate change and the health impacts of the 2019 bushfire season;¹³ in the second, it is likely that the COVID-19 pandemic recovery and stimulus packages will influence a decade of international and Australian climate policy.¹⁴

The 2020 report of the *MJA-Lancet* Countdown represents the work of five Australian institutions in collaboration with University College London, brought together by an evolving partnership between *The Lancet* and *The Medical Journal of Australia*. The collaboration tracks the links between public health and climate change across five domains: climate change impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement. Where possible, we adopt the approach employed by the *Lancet* Countdown, including that used in its 2020 report.¹⁵ Where more appropriate for an Australia-focused assessment, or where it was possible to refine or improve on the original method, the Australian indicators have been modified or an alternative method has been employed. In every case, full details of the data and methods used and the caveats on the research can be found in the Supporting Information.

Given the events of 2019 and the first half of 2020 described above, this year's report focuses on the relationship between health, climate change, and bushfires, highlighting indicators that explore these linkages. The full suite of indicators, reporting across each of the five domains, will return in 2021.

Section 1: Climate change impacts, exposures, and vulnerability

Already, Australians have experienced more intense heatwaves, altered patterns of infectious disease, and food insecurity driven by a changing climate, with the attendant impacts on physical and mental well-being.^{1,16} With average temperatures 1.52°C above and nationally-averaged total rainfall 40% below the 1961-1990 average, 2019 was Australia's hottest and driest year on record, resulting in unprecedented bushfires across the country.¹⁷ In this section, we present short-term and long-term changes in exposure to temperature change and heatwaves, as well as the related effects on bushfire risk and exposure.

1.1 Exposure to temperature change

Rising temperatures and extremes of heat bring the direct effects of heat stress and heat stroke and exacerbations of cardiovascular and renal disease, disproportionately impacting both the Australian public, and vulnerable populations within Australia.

This indicator examines Australia-wide population exposure to rising summer temperature change (December-February), relative to a baseline period of 1981–2010. Relative to this baseline, an ordinary least squares linear regression analysis over the last two decades demonstrates that summer maximum temperatures have risen approximately 1.54°C (Figure 1). Further historical analysis suggests an increasing rate of change over the last 50 summers. Weighting such change by population density as measured in the 2011 national census, the 50-year and 20-year summer maximum temperature rises are 0.14°C and 0.72°C, respectively, revealing the protective nature of the Australian coast, and relative vulnerability of inland populations.

1.2 Health effects of heatwaves

In recent years, multiple studies have demonstrated the effects of heatwaves on excess ambulance demand, hospital admissions and mortality in several sites across Australia.^{18,19} This indicator tracks change in a measure of heatwave intensity – the excess heat factor (EHF) – as it applies to human health.^{20,21} EHF is based on 3-day-averaged daily mean temperatures. Figure 2 shows the Australian averaged accumulated EHF over the past 20 heatwave seasons (November-March).

Calculating two trends through this data (the 20 years presented, and a longer 50-year trend extending from 1970-1971) allows an assessment of long-term change, which demonstrates a 37% increase in EHF over this 20-year period, as well as an understanding of the accelerated rate of change, with a 136% rise seen over the last 20 heatwave seasons. Weighting the accumulated EHF according to the population density has a similar result, with the 50-year and 20-year heatwave season accumulated EHF rises being 33% and 97%, respectively.

1.3 Bushfires

The 2019-2020 bushfires lasted three months in total, spanned 10 million hectares, destroyed more than 3,000 homes, and resulted in 41 deaths directly.²² In total, they cost approximately AUD 100 billion, blanketing Australia's major cities in thick smoke for weeks on end,

resulting in record-levels of air pollution, almost 10 times the ‘hazardous’ rating.²³ In turn, this smoke exposure resulted in an estimated 417 excess deaths, 1,305 asthma emergency department presentations and 3,151 hospital admissions for cardiovascular and respiratory conditions.²⁴ Other health impacts of the fires, yet to be quantified, include acute and lingering mental health impacts of experiencing trauma of evacuation and dislocation, loss of family and friends, loss of property, loss of livelihoods, loss of natural amenity and fear about the future. Additionally, the potential impacts on frontline responders, especially on firefighters – the physical and mental exhaustion, the emotional trauma, the chronic exposure to smoke, and the loss of income for many volunteer firefighters – should not be underestimated.

A robust attribution study of the 2019-2020 bushfires demonstrates the role of climate change in these fires, highlighting the importance of rising temperature extremes and persistent drought, and echoing previous findings for other bushfires.^{13,25,26} This indicator reports change in days where the fire danger index (FDI) is ‘high’ to ‘extreme’ (4-6), as well as population exposure to bushfires since 2001, using the same data and methodology described in the 2020 global *Lancet* Countdown report.¹⁵ Considering area-weighted change, Australia has experienced one of the greatest increases in fire risk globally, with an annual average increase of 30.6 days of high to extreme FDI in 2016-2019 compared with 2001-2004. Figure 3 presents the change in the annual average days of population exposure to bushfires 2001-2004 to 2016-2019 in New South Wales and Australia. Nationally there has been a 22% increase in the annual average in the most recent period compared to the 2001-2004 baseline period. Due to the Black Summer bushfires, the 102,799 person days of exposure to bushfires in 2019 in NSW was by far the highest of any year over the period 2001-2019, with the second highest being 71,452 in 2002 (Figure 3; Supporting Information, Figure A1).

Section 2: Adaptation, planning, and resilience for health

Adaptation is essential to manage the current and future effects of climate change, with multiple interdependencies between the imperative to strengthen the health system and efforts to cope with current public health challenges. Indeed, there are parallels between emergency preparedness measures for extreme weather and those needed to respond to COVID-19.²⁷ This year, Section 2 reports updates on Australian adaptation plans for health (indicator 2.1) and city-level climate change risk assessments (indicator 2.2), and includes further discussion on adaptation responses to Australia's worsening bushfires.

2.1 Australian adaptation plans for health

Despite clear and present need, Australia still lacks a nation-wide climate change adaptation plan for health. However, it is worth noting the leadership from states and territories, with each having a climate change adaptation plan that includes the health sector in some way. In 2019, the Victorian state government published its *Pilot health and human services climate change adaptation action plan 2019–21*,²⁸ becoming the second state after Queensland to have a specific health adaptation plan. Tasmania continues to develop its first health adaptation plan and Western Australia has conducted a Climate and Health Inquiry under the *Public Health Act 2016*.²⁹

2.2 City-level climate change risk assessments

A total of ten Australian city and shire councils reported having completed a climate change risk and vulnerability assessment in 2019 – three more than in 2018.³⁰ The Cities Power Partnership, a network of local government councils leading the response to climate change, now has more than 120 participating councils, an increase of 21% from the 99 we reported in 2019, covering more than 50% of the population.³¹

2.3 Bushfire adaptation

Moving from broad adaptation planning to measures specific to bushfires, continued reluctance to acknowledge the threats posed by climate change at the federal level has hindered progress. The government was warned of the specific dangers of the 2019-20 bushfire season by firefighting experts as early as April 2019.³² Even as the fires played out, the federal government was slow to form any national response to the multijurisdictional crisis.³³

A national taskforce on bushfire adaptation would be an important step for future fire seasons, facilitating planning and prevention (for example, early warning forecasts, hazard reduction, and evacuation planning). Any such effort would increase capacity for resource sharing – including personnel – between regions and states, as this capacity is increasingly diminished when large-scale fires occur simultaneously in multiple jurisdictions. It would also facilitate international coordination with New Zealand, the USA and Canada when resource sharing becomes more difficult as fire seasons in both hemispheres extend and overlap. Part of this work would build on the recommendations from Vardoulakis et al., who explained the need for a national health protection strategy to minimise harm from bushfire smoke exposure.^{34,35}

A national Royal Commission into Australia's devastating Black Summer bushfires has been established (Royal Commission into National Natural Disaster Arrangements) which will look at three key areas:

- Improving natural disaster management coordination across all levels of government;
- Improving Australia's preparedness, resilience, and response to natural disasters, across all levels of government;
- The legal framework for the Commonwealth's involvement in responding to national emergencies and how that works with state and territory legal frameworks.³⁶

Given the escalating impacts of bushfires in Australia and the urgency for adaptation and planning, we intend to introduce a bushfire adaptation indicator in 2021. Such an indicator could track a range of measures, including the prevalence of households with a smoke alarm, response times to structure fires, the number of firefighting personnel, and the number of firefighting aircraft.³⁷

Section 3: Mitigation actions and health co-benefits

Emissions from the 2019-2020 fires in temperate forest in NSW and Victoria were equivalent to adding more than a year's worth of Australian greenhouse gas emissions to the atmosphere, even without taking into account the fires in Queensland, SA, WA and the NT.^{22,38}

Avoiding the worst health impacts of climate change, meeting the UN climate change agreement, and limiting warming to “well below 2°” requires global emissions to rapidly decline over the next ten years, and reach net zero by 2050.^{39,40} Whilst the federal government is yet to join the United Kingdom, the European Union and New Zealand in committing to a net zero target, all Australian state and territory governments have now made such commitments.⁴¹⁻⁴⁸ Australia would have an opportunity to promote investments in a net zero emissions future through the economic stimulus measures in response to COVID-19, for example, through an expansion of its renewable energy systems, green buildings and sustainable transport infrastructure. However, such opportunities have not been prioritised in policy decisions, even though well-designed policies and investments could yield large and immediate health benefits through reductions in air pollution and increased physical activity, in addition to the mitigation of climate change and its impacts.

3.1 Energy system and health

For this year's report, this indicator combines three indicators of mitigation of Australia's energy system, using data from the International Energy Agency.⁴⁹⁻⁵¹ Here, it is clear that Australia's mitigation response remains inadequate. Australia is the only OECD country to have worsened the carbon intensity of its energy supply over the last three decades, which is now 36% worse than the global average. Australia continues to have a heavy reliance on coal, which represented a share of 60.4% of total power generation in 2018 (a drop from 62.8% in 2017). Wind and solar power are growing; however, they remain a small share of total generation, rising from 8% in 2017 to 9.6% in 2018.

3.2 Exposure to air pollution in cities

The annual average background concentration of PM_{2.5} in typical urban settings in Australia is generally low by international standards. However, the contribution of extreme events such as bushfire smoke and dust storms, as well as regular seasonal variation due to dry season fires in the NT and domestic wood heater use has led to periods of harmful pollution levels. The majority of Australia's premature deaths attributable to PM_{2.5} come from households, road transport and industry – providing opportunities to improve health through mitigation policies.¹⁵ This analysis calculates average PM_{2.5} concentration for all major Australian cities from 2000 to 2019 where data is available. We averaged city-specific levels by state and territory as shown in Figure 4. Whilst the annual average PM_{2.5} concentrations were generally below the Australian advisory reporting standard of 8 µg/m³, major bushfire seasons such as those that occurred in NSW in 2001-2002, 2002-2003 and 2019-2020 were so extreme that they influenced the annual average PM_{2.5} concentrations in those years. At 11.2 µg/m³, the NSW annual average PM_{2.5} concentration in 2019 far exceeded all previous years across all states and territories in this 20-year analysis. Similarly, the monthly PM_{2.5} concentration in NSW at the end of 2019 was the highest of any month, reaching an average of almost 30 µg/m³.

Section 4: Economics and finance

Extensive research has made clear that the benefits of a low-carbon transition combined with avoided costs of climate change, far outweigh any initial investment costs. One recent study estimated that, compared with current commitments, limiting warming to 1.5°C by 2100 would generate a global accumulated net benefit of US\$264-610 trillion – 3.1 to 7.2 times the 2018 global economy.⁵² Recent trends in economic losses due to climate-related extreme events and economic costs of air pollution (indicators 4.1 and 4.2) are presented in this section, with other indicators of the transition to a zero carbon economy, including investments and employment in zero carbon energy, returning in 2021.

4.1 Economic losses due to climate-related extreme events

Total insured economic losses from disaster events are tracked in this indicator, based on numbers provided by the Insurance Council of Australia.⁵³ Figure 5 plots inflation-adjusted cumulative annual insured losses arising from bushfires, cyclones, flooding, hailstorms, and tornados from 2000 to 2019. For 2019, the estimate for total annual insured losses from these events was \$3.70 billion – the second highest across the 20-year period. The severe bushfires across NSW, Queensland, SA and Victoria accounted for \$2.2 billion of these losses, although the total costs of these bushfires could be orders of magnitude higher.²³ Data from 2019 captured a second noteworthy extreme event: torrential rainfall and widespread flooding in North Queensland over January and February, resulting in losses of approximately \$1.27 billion.

4.2 Economic costs of air pollution

New to the 2020 report, this indicator tracks the economic cost of air pollution on human health. In 2015 more than 2,500 deaths (1.6% of total deaths), corresponding to approximately 29,000 years of life lost (YLL) were attributable to urban ambient PM_{2.5} in Australia.⁵⁴ Additionally, an estimated 8,700 years lived with disability in Australia in 2015 were attributable to air pollution.⁵⁴ Air pollution is also one of the 10 leading risk factors contributing to fatal burdens for males in the 85-94 and 95+ age groups, and females in the 75-84, 85-94 and 95+ age groups. Applying an estimated economic value of a statistical life year of \$185,000 for 2015,⁵⁵ the health costs from mortality due to air pollution alone are estimated to be around \$5.3 billion per year (however this estimate is sensitive to strong assumptions and details of the method chosen and may not be easily comparable to other estimates of health costs).

As discussed in the previous sections, climate change and the rising risk of bushfires in Australia can be expected to exacerbate the economic cost of air pollution, with large numbers of deaths and hospitalisations already attributed to air pollution from the 2019-2020 bushfires.²⁴

Section 5: Public and political engagement

As the preceding sections have highlighted, the health impacts of climate change are worsening rapidly, necessitating stronger engagement and understanding across all spheres of society. Section 5 examines this, centring on engagement within the media and the scientific community (indicators 5.1 and 5.2).

5.1 Media coverage of health and climate change

This indicator continues to track Australian media coverage on health and climate change. We used the same methods as reported previously, analysing 13 national and regional high-circulation English-language newspapers from 2008 to 2019, as well as Australian Broadcasting Cooperation (ABC) online news and transcripts of the ABC online programs.¹ It is clear that the extreme heat and bushfires of 2019 have resulted in increased media engagement with health and climate change. With 127 pieces in 2019, the total number of newspaper articles on health and climate change was almost double the number (65) in 2018. National newspapers have had the most growth, followed by newspapers in Sydney and Hobart (Figure 6). At the same time, online coverage from the ABC on health and climate change has more than tripled (Supporting Information, Figure A2).

5.2 Scientific engagement in health and climate change

Using search terms in Scopus databases as described in the 2019 *MJA-Lancet* Countdown report, this indicator tracks scientific publications on health and climate change in Australia.¹ The number of publications in 2019 (99) represents a significant increase from the 66 in 2018, standing as the highest number recorded over the past decade (Figure 7). In a preliminary analysis of the first four months of 2020, this trend continues, and there is a clear increasing proportion of studies related to bushfire impacts and management; 22% compared to 7% in 2019.

In this report we also present, for the first time, data on National Health and Medical Research Council (NHMRC) health and climate change grant applications from 2000 to 2018 (Figure 8). After a period of limited grant applications on health and climate change per year (2-3) from 2000 to 2005, the number peaked at 33 in 2010, due to a partnership between the NHMRC and the former Department of Climate Change. However, since then the annual rate has decreased every year, to seven applications in 2018. In keeping with the field, the success rate of these applications has been volatile, dropping below 20 percent in the last decade and with none of the 29 applications submitted in 2013 and 2014 being successful. The NHMRC has since committed \$10 million over five years for a special research initiative – commencing in 2021 – to boost research capacity and capability to address health implications of environmental change. In addition, \$5 million funds from the Medical Research Future Fund (MRFF) were allocated for research into the health impacts of bushfire in early 2020.

Conclusion: the *MJA-Lancet* Countdown in 2020

With 2019 being the hottest year on record in Australia, the indicators of the 2020 report of the *MJA-Lancet* Countdown document concerning trends in exposure to high summer temperatures, heatwaves and bushfires.

The 2019-2020 bushfires were intense and expansive, resulting in approximately 450 deaths due to direct injury and air pollution exposure. The air pollution was so severe that it made the NSW annual average PM_{2.5} concentration by far the highest in the past 20 years. The direct insured losses of the bushfires are estimated at \$2.21 billion over the five-month period, while many other impacts remain uncounted.

Despite a lack of adaptive capacity and of progress on reducing emissions, there is growing awareness of and engagement with the links between health and climate change. This is illustrated in the doubling in the number of newspaper articles and the 50% increase in scientific publications on the topic in Australia from 2018 to 2019. Australia's leading medical and nursing bodies have recognised climate change as a health emergency, and each state and territory government has committed to a net-zero target by 2050 at the latest.

As Australia recovers from the compounded effects of the bushfires and begins to emerge from the COVID-19 pandemic, the health profession has a pivotal role to play. It is uniquely suited to integrate the response to these short-term threats, with the longer-term public health implications of climate change, and to ensuring that the economic recovery from COVID-19 aligns and strengthens Australia's commitments under the Paris Agreement.

References

1. Beggs PJ, Zhang Y, Bambrick H, et al. The 2019 report of the *MJA-Lancet* Countdown on health and climate change: a turbulent year with mixed progress. *Med J Aust* 2019; 211(11): 490-491.e21. <https://www.mja.com.au/journal/2019/211/11/2019-report-mja-lancet-countdown-health-and-climate-change-turbulent-year-mixed>
2. Watts N, Amann M, Arnell N, et al. The 2019 report of The *Lancet* Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet* 2019; 394(10211): 1836-1878.
3. Australian Medical Association. Climate change is a health emergency. Barton: AMA, 2019. <https://ama.com.au/media/climate-change-health-emergency> (accessed Jun 2020).
4. Australasian College for Emergency Medicine. Statement on climate change. West Melbourne: ACEM, 2019. <https://acem.org.au/News/May-2019/Statement-on-climate-change> (accessed Jun 2020).
5. The Royal Australasian College of Physicians. Leading medical group declares public health emergency and calls for national strategy to tackle climate change. Sydney: RACP, 2019. <https://www.racp.edu.au/news-and-events/media-releases/leading-medical-group-declares-public-health-emergency-and-calls-for-national-strategy-to-tackle-climate-change> (accessed Jun 2020).
6. Hendrie D. Climate change is a health emergency, RACGP declares. 2019. <https://www1.racgp.org.au/newsgp/racgp/climate-change-is-a-health-emergency-racgp-declare> (accessed Jun 2020).
7. Australian College of Rural and Remote Medicine. ACRRM recognises climate change as a rural health emergency. Brisbane; ACRRM, 2019. <https://www.acrrm.org.au/about-us/news-events/media-releases/2019/11/20/acrrm-recognises-climate-change-as-a-rural-health-emergency> (accessed Jun 2020).
8. Australian and New Zealand College of Anaesthetists. ANZCA Council Statement on Climate Change. Melbourne: ANZCA, 2020. <https://www.anzca.edu.au/about-us/our-culture/environmental-sustainability> (accessed Jul 2020).
9. The Royal Australian and New Zealand College of Psychiatrists. RANZCP supports climate emergency. Melbourne: RANZCP, 2020. <https://www.ranzcp.org/news-policy/news/ranzcp-supports-climate-emergency> (accessed Jun 2020).

10. College of Intensive Care Medicine of Australia and New Zealand. Climate change statement. Prahran: CICM, 2020. https://cicm.org.au/CICM_Media/CICMSite/Files/Climate-Change-Statement_1.pdf (accessed Jun 2020).
11. Australian College of Nursing. Climate change a global health emergency. Deakin: ACN, 2019. <https://www.acn.edu.au/media-release/climate-change-global-health-emergency> (accessed Jun 2020).
12. Australian Nursing & Midwifery Federation. Open letter calls on every federal parliamentary candidate to address climate health emergency. Kingston: ANMF, 2019. <https://anmf.org.au/news/entry/open-letter-calls-on-every-federal-parliamentary-candidate-to-address-clima> (accessed Jun 2020).
13. van Oldenborgh GJ, Krikken F, Lewis S, et al. Attribution of the Australian bushfire risk to anthropogenic climate change. *Nat Hazards Earth Syst Sci Discuss* 2020. <https://doi.org/10.5194/nhess-2020-69>
14. Hepburn C, O’Callaghan B, Stern N, et al. Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxford Review of Economic Policy* 2020. <https://doi.org/10.1093/oxrep/graa015>
15. Watts N, Amann M, Arnell N, et al. The 2020 report of the *Lancet* Countdown on health and climate change. *Lancet* 2020; In press.
16. Zhang Y, Beggs PJ, Bambrick H, et al. The *MJA-Lancet* Countdown on health and climate change: Australian policy inaction threatens lives. *Med J Aust* 2018; 209(11): 474.e1-474.e21. <https://www.mja.com.au/journal/2018/209/11/mja-lancet-countdown-health-and-climate-change-australian-policy-inaction>
17. Bureau of Meteorology. Annual climate statement 2019. Melbourne: BOM, 2020. <http://www.bom.gov.au/climate/current/annual/aus/> (accessed Jun 2020).
18. Campbell S, Remenyi TA, White CJ, Johnston FH. Heatwave and health impact research: a global review. *Health & Place* 2018; 53: 210-218.
19. Watson KE, Gardiner KM, Singleton JA. The impact of extreme heat events on hospital admissions to the Royal Hobart Hospital. *J Public Health (Oxf)* 2020; 42(2): 333-339.
20. Nairn JR, Fawcett RJB. The excess heat factor: a metric for heatwave intensity and its use in classifying heatwave severity. *Int J Environ Res Public Health* 2015; 12(1): 227–253.
21. Nairn J, Fawcett R. Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia. CSIRO and Australian Government Bureau of Meteorology, 2013. (CAWCR Technical

- Report No. 060) https://www.cawcr.gov.au/technical-reports/CTR_060.pdf (accessed Jun 2020).
22. Parliamentary Library. 2019–20 Australian bushfires—frequently asked questions: a quick guide. Canberra: Parliamentary Library, 2020. https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1920/Quick_Guides/AustralianBushfires (accessed Jun 2020).
 23. Read P, Denniss R. With costs approaching \$100 billion, the fires are Australia’s costliest natural disaster. *The Conversation* 2020; 17 Jan. <https://theconversation.com/with-costs-approaching-100-billion-the-fires-are-australias-costliest-natural-disaster-129433> (accessed Jun 2020).
 24. Borchers Arriagada N, Palmer AJ, Bowman DMJS, et al. Unprecedented smoke-related health burden associated with the 2019-20 bushfires in eastern Australia. *Med J Aust* 2020; 213(6). <https://www.mja.com.au/journal/2020/213/6/unprecedented-smoke-related-health-burden-associated-2019-20-bushfires-eastern>
 25. Lewis SC, Blake SAP, Trewin B, et al. Deconstructing factors contributing to the 2018 fire weather in Queensland, Australia. *Bull Amer Meteor Soc* 2020; 101(1): S115-S122.
 26. Tett SFB, Falk A, Rogers M, et al. Anthropogenic forcings and associated changes in fire risk in Western North America and Australia during 2015/16. *Bull Amer Meteor Soc* 2018; 99(1): S60-S64.
 27. Sheehan MC, Fox MA. Early warnings: the lessons of COVID-19 for public health climate preparedness. *Int J Health Services* 2020; 50(3): 264-270.
 28. Department of Health and Human Services. Pilot health and human services climate change adaptation action plan 2019–21. Melbourne: DHHS, Victorian State Government, 2019. <https://www.dhhs.vic.gov.au/pilot-health-and-human-services-climate-change-adaptation-action-plan-2019-21-0> (accessed Aug 2020).
 29. Weeramanthri TS, Joyce S, Bangor-Jones R. Climate health inquiry: where sustainability, public health law and climate action intersect. *Med J Aust* 2020; 212(8). <https://www.mja.com.au/journal/2020/212/8/climate-health-inquiry-where-sustainability-public-health-law-and-climate-action>
 30. CDP. Explore CDP cities and regions data [Annual cities survey dataset]. London: CDP, 2020. <https://data.cdp.net/> (accessed Jul 2020).
 31. Cities Power Partnership [website]. <https://citiespowerpartnership.org.au/> (accessed Jun 2020).
 32. Cox L. Former fire chiefs warn Australia unprepared for escalating climate threat. *The Guardian* (Australia edition) 2019; 10 Apr.

- <https://www.theguardian.com/australia-news/2019/apr/09/former-fire-chiefs-warn-australia-unprepared-for-escalating-climate-threat> (accessed Jul 2020).
33. Davidson H. Scott Morrison rejects calls for more bushfire help, saying volunteer firefighters ‘want to be there’. *The Guardian* (Australia edition) 2019; 10 Dec. <https://www.theguardian.com/australia-news/2019/dec/10/scott-morrison-rejects-calls-for-more-help-saying-volunteer-firefighters-want-to-be-there> (accessed Jul 2020).
 34. Vardoulakis S, Marks G, Abramson MJ. Lessons learned from the Australian bushfires: climate change, air pollution, and public health. *JAMA Intern Med* 2020; 180(5): 635-636.
 35. Vardoulakis S, Jalaludin BB, Morgan GG, et al. Bushfire smoke: urgent need for a national health protection strategy. *Med J Aust* 2020; 212(8): 349-353.e1.
 36. Prime Minister of Australia. National Royal Commission into Black Summer bushfires established. Canberra: PMA, 2020. <https://www.pm.gov.au/media/national-royal-commission-black-summer-bushfires-established> (accessed Jul 2020).
 37. National Aerial Firefighting Centre. Fleet. East Melbourne: NAFC, 2020. http://www.nafc.org.au/?page_id=168 (accessed Jul 2020).
 38. Department of Industry, Science, Energy and Resources. Estimating greenhouse gas emissions from bushfires in Australia’s temperate forests: focus on 2019-20. Canberra: DISER, 2020. <https://www.industry.gov.au/data-and-publications/estimating-greenhouse-gas-emissions-from-bushfires-in-australias-temperate-forests-focus-on-2019-20> (accessed Jun 2020).
 39. Intergovernmental Panel on Climate Change (IPCC). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte V, Zhai P, Pörtner H-O, et al., editors]. Geneva: World Meteorological Organization, 2018. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf (accessed Aug 2020).
 40. United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement. Bonn: UNFCCC, 2015. <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement> (accessed Jun 2020).
 41. Department of Planning, Industry and Environment. Net Zero Plan Stage 1: 2020-2030. Sydney: DPIE, 2020. <https://www.environment.nsw.gov.au/topics/climate-change/net-zero-plan> (accessed Jun 2020).

42. Department of Environment, Land, Water and Planning. Emissions reduction targets. Melbourne: DELWP, 2020.
<https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets> (accessed Jun 2020).
43. Australian Capital Territory (ACT) Government. ACT's Climate Strategy to a Net Zero Emissions Territory: Discussion Paper. Canberra: ACT Government, 2017. https://www.yoursay.act.gov.au/download_file/1487/647 (accessed Aug 2020).
44. Department of Premier and Cabinet. Climate change in Tasmania: Tasmania's emissions. Hobart: DPC, 2020.
http://www.dpac.tas.gov.au/divisions/climatechange/tasmanias_climate_change_action_plan_20172021/climate_change_in_tasmania (accessed Jun 2020).
45. Department for Environment and Water. South Australia's greenhouse gas emissions. Adelaide: DEW, 2020.
<https://www.environment.sa.gov.au/topics/climate-change/south-australias-greenhouse-gas-emissions#:~:text=In%20February%202020%2C%20the%20Government,net%20zero%20emissions%20by%202050> (accessed Jun 2020).
46. Department of Environment and Heritage Protection. Pathways to a clean growth economy: Queensland Climate Transition Strategy. Brisbane: Queensland Government, 2020.
https://www.qld.gov.au/data/assets/pdf_file/0026/67283/qld-climate-transition-strategy.pdf (accessed Aug 2020).
47. Department of Water and Environmental Regulation. Climate change. Joondalup: Government of Western Australia, DWER, 2019.
<https://www.der.wa.gov.au/your-environment/climate-change> (accessed Jun 2020).
48. Department of Environment and Natural Resources. Northern Territory Climate Change Response: Towards 2050. Palmerston: Northern Territory Government, DENR, 2020.
https://denr.nt.gov.au/data/assets/pdf_file/0005/904775/northern-territory-climate-change-response-towards-2050.pdf (accessed Aug 2020).
49. International Energy Agency (IEA). World Energy Outlook 2019. Paris: IEA, 2019. <https://www.iea.org/reports/world-energy-outlook-2019> (accessed Jun 2020).
50. International Energy Agency (IEA). IEA Statistics Report. Paris: IEA, 2020.
<https://www.iea.org/reports/world-energy-balances-overview> (accessed Aug 2020).
51. International Energy Agency (IEA). World Extended Energy Balances. UK Data Service, 2020. <https://www.iea.org/reports/world-energy-balances-overview> (accessed Aug 2020).

52. Wei Y-M, Han R, Wang C, et al. Self-preservation strategy for approaching global warming targets in the post-Paris Agreement era. *Nature Communications* 2020; 11(1): 1624.
53. Insurance Council of Australia (ICA). ICA Dataglobe. Sydney: ICA, 2020. <http://www.icadataglobe.com/access-catastrophe-data/> (accessed Jun 2020).
54. Australian Institute of Health and Welfare. Australian burden of disease study: impact and causes of illness and death in Australia 2015. Australian Burden of Disease series no. 19. Cat. no. BOD 22. Canberra: AIHW, 2019.
55. Office of Best Practice Regulation. Best practice regulation guidance note: value of statistical life. Canberra: Australian Government, OBPR, 2014. www.dpmc.gov.au/sites/default/files/publications/Value_of_Statistical_Life_guidance_note.pdf (accessed Jun 2020).
56. National Health and Medical Research Council. Background paper: NHMRC's role in addressing health implications of environmental change. Canberra: NHMRC, 2019.

Photographs, graphs and illustrations

Figure 1. Nationally averaged Australian summer (December–February) maximum temperature anomalies for the past 20 summers (2000-2001 to 2019-2020). The base period for the anomalies is 1981–2010. The black trend line is calculated over the past 50 summers (1970-1971 to 2019-2020), while the grey trend line is calculated over the past 20 summers

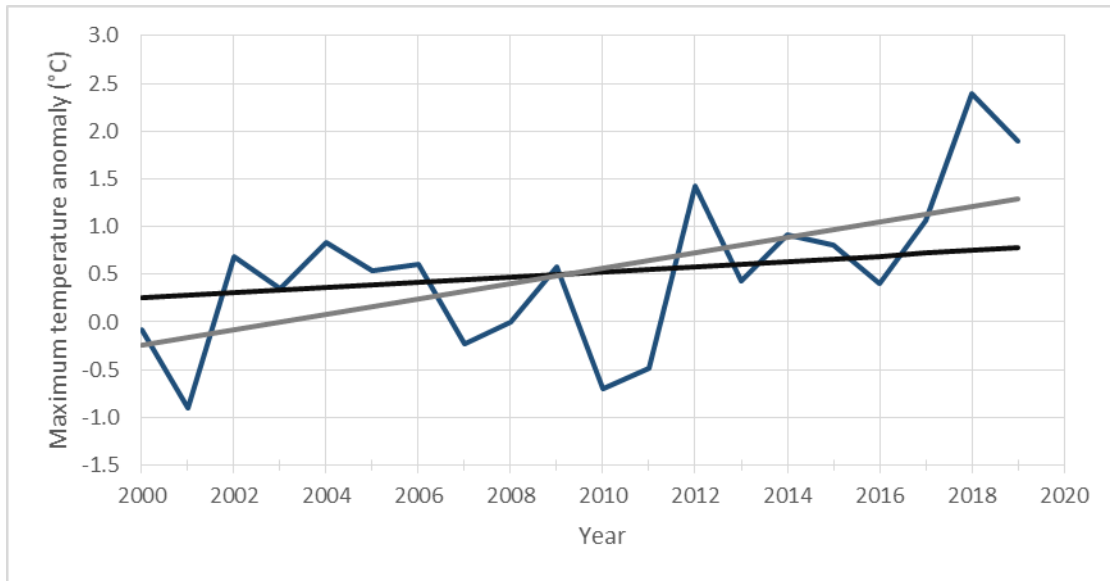


Figure 2. Nationally averaged Australian heatwave season (November–March) accumulated excess heat factor (EHF) for the past 20 heatwave seasons (2000–2001 to 2019–2020). The black trend line is calculated over the past 50 heatwave seasons (1970–1971 to 2019–2020), while the grey trend line is calculated over the past 20 heatwave seasons

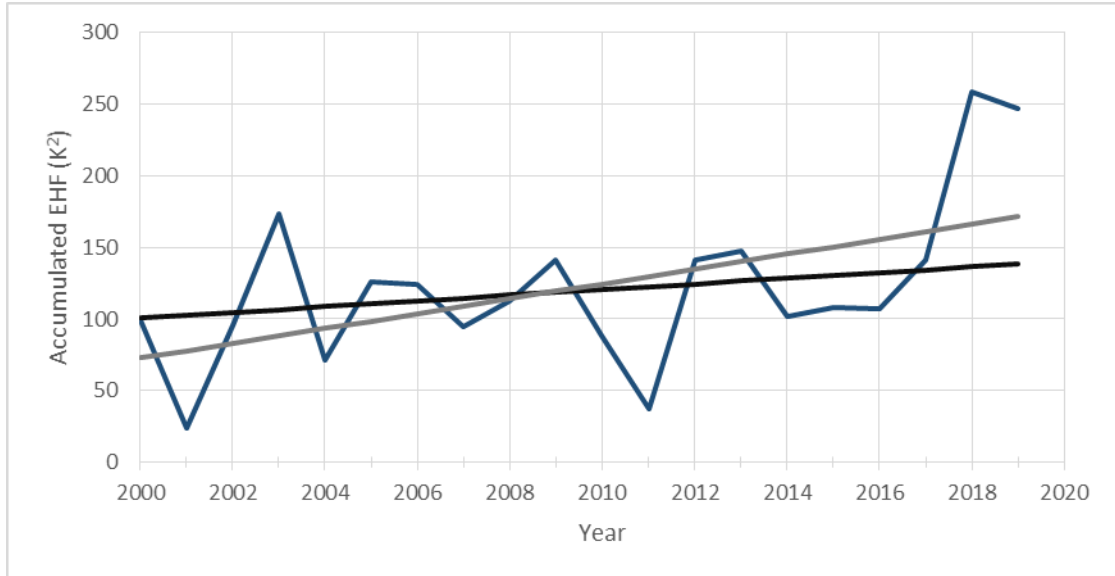


Figure 3. Annual person days exposed to bushfires during 2001-2004 and 2016-2019 in New South Wales and Australia

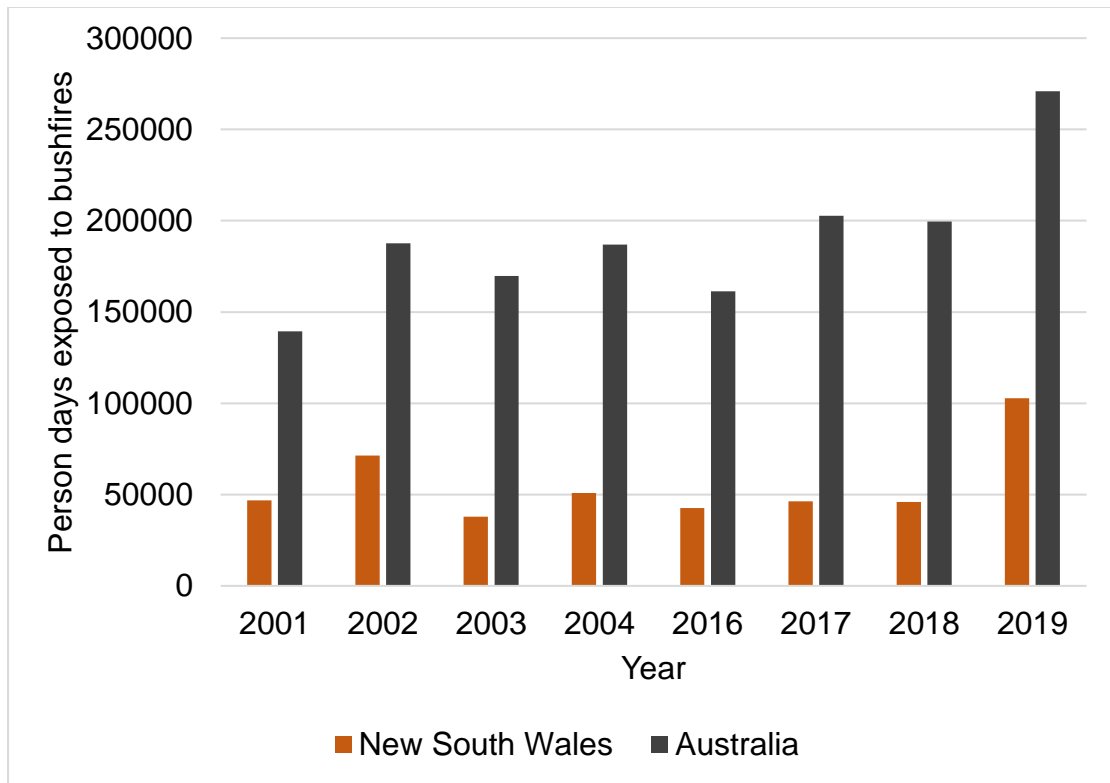


Figure 4. Annual and monthly average PM_{2.5} for cities in each Australian state and territory from 2000 to 2019 overlaid together in smoothed time-series plots to display the contribution of major fire events (2001/02, 2002/03 and 2019/20) and dust storms (2009) to the annual averages. PM_{2.5} units are $\mu\text{g}/\text{m}^3$

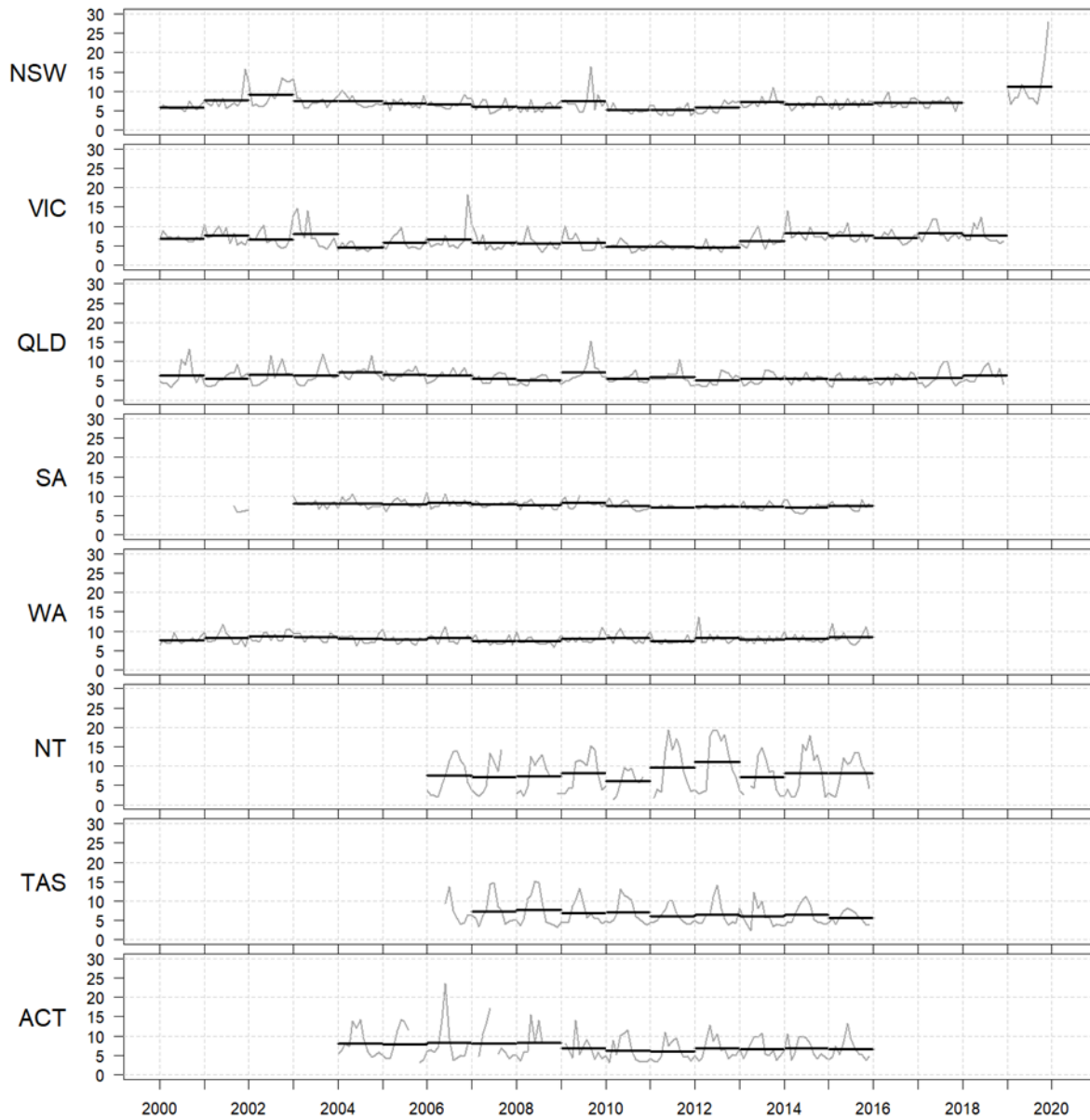
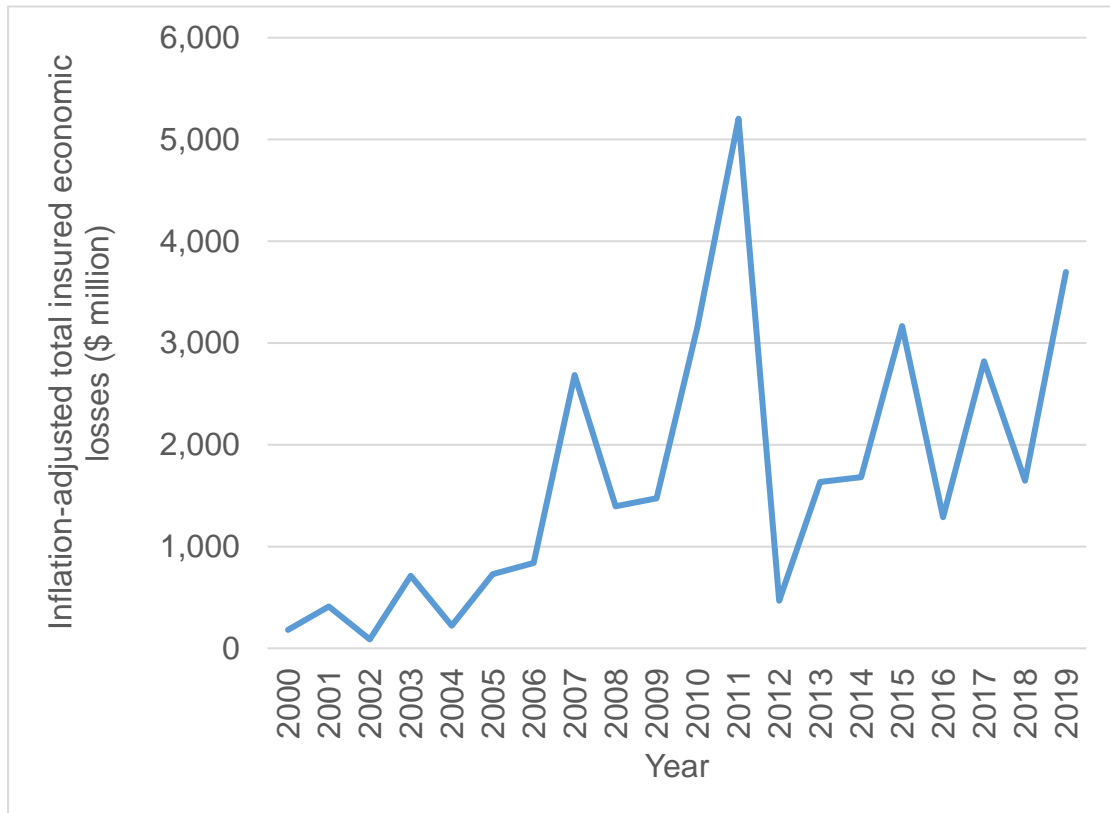
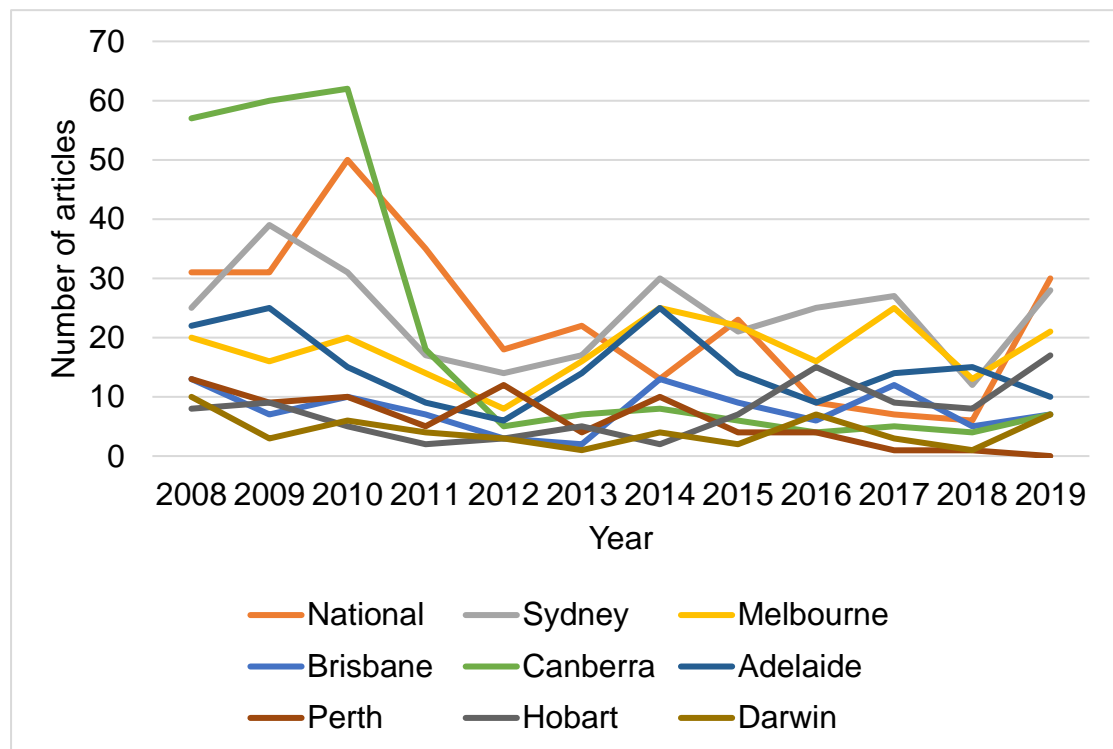


Figure 5. Annual inflation-adjusted total insured economic losses in Australia from bushfires, cyclones, flooding, hailstorms, storm flooding, and tornados for the period 2000 – 2019 based on the Historical Catastrophe Database of the Insurance Council of Australia (ICA)



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Figure 6. Annual number of media articles on health and climate change by regions in Australia, 2008-2019



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Figure 7. Number of scientific publications on health and climate change in Australia, 2008-2019

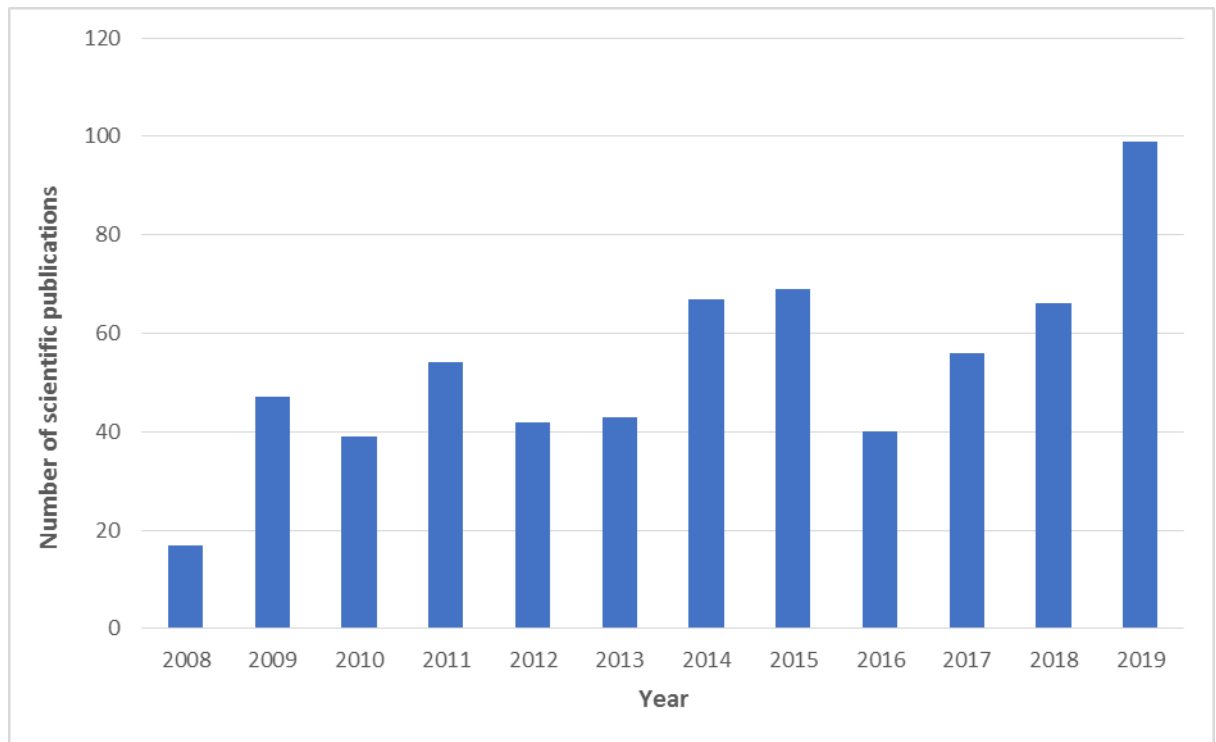


Figure 8. Funded and not-funded National Health and Medical Research Council (NHMRC) grant applications with a focus on health and climate change, and success rate, between 2000 and 2018. Source: NHMRC⁵⁶

