Supporting Information

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

Appendix to: Zhang Y, Beggs PJ, McGushin A, et al. The 2020 special report of the *MJA–Lancet* Countdown on health and climate change: lessons learnt from Australia's "Black Summer". *Med J Aust* 2020; doi: 10.5694/mja2.50869.

Appendix: The 2020 special report of the *MJA-Lancet* Countdown on health and climate change: lessons learnt from Australia's "Black Summer"

This Appendix includes details of the data, methods, and caveats for each of the 12 indicators assessed in the 2020 *MJA-Lancet* Countdown. It also includes two additional figures that further illustrate indicators 1.3 and 5.1. Finally, it includes, for several indicators, current thoughts regarding the potential future form of the indicator. This is provided in the context of this being the third *MJA-Lancet* Countdown annual report and the acknowledgement that its indicators, like those of the *Lancet* Countdown, will likely continue to develop in future annual assessments.

Section 1: Climate change impacts, exposures, and vulnerability

1.1 Exposure to temperature change

Data

The temperature dataset employed for this calculation is the Bureau of Meteorology's operational Australian Climate Observations Reference Network - Surface Air Temperature (ACORN-SAT) curated temperature network analyses.[1]

Methods

Fields of monthly maximum surface air temperature on a 0.25° latitude/longitude grid were extracted for the summer months (December-February) of the years 1970-1971 to 2019-2020 and time-averaged to obtain annual grids of summertime maximum temperature. The baseline grid was the 30-year average of summertime maximum temperatures during 1981-2010. Summertime anomaly grids (ie, departures from the baseline) were area-averaged to produce a time series of nationally averaged summer maximum temperature anomalies. Ordinary least squares linear regression was calculated over the last 50 summers (1970-1971 to 2019-2020); and 20 summers (2000-2001 to 2019-2020).

Additional calculations were performed, replacing the area weighting in the area averaging process with a population-weight matrix grid obtained from gridded population data released by the Australian Bureau of Statistics from its 2011 national census. The population weighting in the calculation assumes that the relative population distribution across the country remains unchanged, without assuming specifically that the national-total population remains unchanged.

1.2 Health effects of heatwaves

Data

The heatwave dataset employed for this calculation is the Bureau of Meteorology's national Excess Heat Factor (EHF) heatwave analysis.[2,3]

Methods

0.25°-resolution national grids of EHF were extracted for three-day periods containing days during the heatwave season (November-March) of 1970-1971 to 2019-2020, with tapered down-weighting for the four three-day periods (two at each end) which are only partially within the November-March season. The data from each season were accumulated over the season to create grids of annual heat load. Only positive values of the EHF (positive values indicating the presence of heatwave, negative values its absence) are included in the accumulation. The annual grids were area-averaged to produce a time series of nationally averaged annual heat load. Ordinary least squares linear regression was calculated over the last 50 heatwave seasons (1970-1971 to 2019-2020); and 20 heatwave seasons (2000-2001 to 2019-2020).

Additional calculations were performed, replacing the area weighting in the area averaging process with a population-weight matrix grid obtained from gridded population data released by the Australian Bureau of Statistics from its 2011 national census. The population weighting in the calculation assumes that the relative population distribution across the country remains unchanged, without assuming specifically that the national-total population remains unchanged.

1.3 Bushfires

Data

Collection 6 active fire product from the Moderate Resolution Imaging Spectroradiometer (MODIS).[4] This contains both Terra (from November 2000) and Aqua (from July 2002) pixels in the same annual file. Fire danger indices historical data produced by the Copernicus Emergency Management Service for the European Forest Fire Information System (EFFIS).[5] Population data from the NASA Socioeconomic Data and Applications Center (SEDAC) Gridded Population of the World (GPW v4.11).[6]

Methods

The change in population exposure to bushfires is represented as the change in the average annual number of days people were exposed to bushfire. Satellite-observed active fire spots were aggregated and spatially joined with gridded population data on a 10 km x 10 km resolution grid. Grid cells with a population density ≥ 400 persons/km^2 were excluded to remove urban heat sources unrelated to bushfires. The mean annual number of person-days exposed to bushfire during the most recent four years was compared with the baseline period of 2001-04.

The fire danger risk is represented in terms of the Fire Danger Index (FDI). Provided by ECMWF ERA5 atmospheric reanalysis, FDI is a numeric rating with values 1-6 representing very low, low, medium, high, very high and extreme fire danger risk, respectively. Daily FDI data, available from 3 January 1979 through 26 December 2019, were aggregated so as to obtain the yearly number of days of each fire danger risk level at every 0.25° x 0.25° grid cell. The changes in mean number of days exposed to very high or extreme fire danger risk (defined as FDI ≥ 5) were collected for the most recent available period, 2016 to 2019, and compared with a baseline from 2001 to 2004.

Gridded population density data (ie, population count per square kilometre) from NASA SEDAC GPW v4.11 dataset, were retrieved for the years 2000, 2005, 2010, 2015, and 2020. The data set with a spatial resolution of 2.5’ × 2.5’ (around 5km x 5km) was used. Population density data were re-gridded to the spatial resolution of the fire danger data using a conservative method (ie, the total population is conserved) and further linearly interpolated for each year from 2000-2019. The re-gridded population data were used to calculate population-weighted mean days of fire risk. Similar to bushfire exposure, grid cells with a population density ≥ 400 persons/km^2 were excluded in the calculation of changes in mean number of days exposed to very high or extreme fire danger risk.[7]

Future form of indicator

The future form of this indicator is expected to be the same as that for the equivalent indicator in Watts et al.[7].

Section 2: Adaptation, planning, and resilience for health

Data

Data for this section are the same as those used for Indicators 2.1 (Australian adaptation plans for health), 2.2 (City-level climate change risk assessments), and 2.5 (National assessments of climate change impacts, vulnerability and adaptation for health) in Beggs et al.[8], with the addition of new data on Australia’s emergency response to the summer bushfires of 2019-2020, as an indication of the current status of Australia’s adaptation, planning and resilience to bushfire weather that is increasingly intense, more geographically widespread, and occurs over an increasingly extended season.

Methods

Methods for this section are the same as those used for Indicators 2.1 (Australian adaptation plans for health), 2.2 (City-level climate change risk assessments), and 2.5 (National assessments of climate change impacts, vulnerability and adaptation for health) in Beggs et al.[8] with the addition of a literature search for material (peer-reviewed and other) relating to Australia’s 2019-2020 bushfire response. Peer-reviewed literature was found by searching PubMed using the terms “bushfire” AND “Australia” for publications just in the year 2020, yielding a total of six initial results; one on removing smoke damage from smoke affected wine grapes and another on post-fire seed dispersal were removed, leaving four which were at least partially relevant.[9-12] No records were found with the same search terms on the Web of Science databases, while this same search in Google Scholar yielded more than 1000 results, including the four found on PubMed, with varying degrees of relevance. These were not systematically reviewed for this section, with only a small number cited in this summary, along with relevant government and media reports found through Google.

Caveats

Caveats for this section are the same as for Indicators 2.1 (Australian adaptation plans for health), 2.2 (City-level climate change risk assessments), and 2.5 (National assessments of climate change impacts, vulnerability and adaptation for health) in Beggs et al.[8], with an additional caveat that the review of bushfire adaptation, planning and resilience presented here is by no means exhaustive, limited by available space and at the time of writing there is little in the way of adaptation-related analyses available in the peer-reviewed literature. This section therefore summarises just a few key observations from the recent fire season as they relate to Australia's preparedness and adaptation to increasingly dangerous fire weather.

Future form of indicator

Indicators 2.1 and 2.5 in Beggs et al.[8] overlap and could be merged in subsequent years, especially as this is not a rapidly developing area. Health adaptation to bushfires in Australia could form its own, novel indicator in subsequent updates and is significant enough for a substantial review.

A measure of whether bushfire adaptation is improving over time would be the establishment of a national taskforce and the adoption of a national health protection strategy, or similar. Further measures could include number of firefighting personnel, the prevalence of households with a smoke alarm, response times to structure fires, and the number of firefighting aircraft.[13]

Section 3: Mitigation actions and health co-benefits

3.1 Energy system and health

Data

Carbon intensity data are based on the International Energy Agency (IEA) dataset, CO_2 Emissions From Fuel Combustion: CO_2 Indicators, accessed via the UK data service,[14] and supplemented with additional data for 2018, 2019 and 2020.[15-17] Data on share of coal and renewable energy are based on the extended energy balances from the IEA. The specific dataset is called World Extended Energy Balances (for 2019), and is sourced via the UK data service.[18]

Methods

Carbon intensity of the energy system is calculated based on total CO_2 emissions from fossil fuel combustion divided by Total Primary Energy Supply (TPES). TPES reflects the total amount of primary energy used in a specific country, accounting for the flow of energy imports and exports.

The indicator on the share of electricity generation from coal and wind and solar is estimated based on electricity generated from coal plant or wind and solar (TWh) as a percentage of total electricity generated.

3.2 Exposure to air pollution in cities

Data

Air pollution monitoring data for ambient airborne fine particulate matter ($PM_{2.5}$) were utilised from the year 2000 (when monitoring became more comprehensive) to 2019 from state government agency ground-based monitoring stations around Australia. The majority of monitoring stations were located in major cities allowing assessment of air pollution concentrations for larger population centres.

Data were provided by the responsible agency in each state and territory as follows: Environment Protection Authority Victoria, New South Wales Department of Planning, Industry and Environment, Queensland Department of Environment and Science, Environment Protection Authority South Australia, Environment Protection Authority Tasmania, Department of Water and Environmental Regulation Western Australia, Environment Protection and Water Regulation Australian Capital Territory and Northern Territory Environment Protection Authority.

Spatial boundaries and populations were obtained from the Australian Bureau of Statistics dataset "1270.0.55.001 - Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas, July 2016".

Methods

Average $PM_{2.5}$ ($\mu g/m^3$) levels were calculated for each city with more than 100,000 population resident in 2016 by taking the average of all monitors within 50km of the city centres. We first calculated a daily average for monitor stations where more than 70% of observations in a 24 hour period were present, and used these to calculate the average for each city per day. We then computed monthly averages for each city for months with more than 19 observations present. We averaged all the major cities within the states and territories to monthly time-series and finally into annual averages (for years where more than 7 months were present).

We displayed the annual and monthly averages overlaid together in smoothed time-series plots to show the contribution of each month to the annual averages. This method provides a general approach to highlighting major pollution events, such as bushfire season events (generally in summer) as shown by the specific major bushfire events in 2001/02, 2002/03 and 2019/20. Other extreme pollution events such as the 2009 dust storm in the eastern states are also illustrated in the monthly data. These events were so extreme they elevated the annual averages.

Caveats

We were not able to access data for all state and territory government agencies to provide updated monitored $PM_{2.5}$ data to 2019. The other caveats for this indicator in Zhang et al.[19] also apply to our current use of this indicator.

Future form of indicator

Future improvements of this indicator are the same as those described in Zhang et al.[19].

Section 4: Economics and finance

4.1 Economic losses due to climate-related extreme events

Data

Reported data are based on figures on total insured economic losses from disaster events provided in the Historical Catastrophe Database 1967 - Present Day of the Insurance Council of Australia.[20] The database includes recorded data from the ICA on disaster events that have occurred over the last 50 years in the Australian market.

Cumulative annual insured losses arising from bushfires, cyclones, flooding, hail storms, storm flooding, tornados and other climate-related extreme events are considered. Extreme events related to earthquakes, arson, gas disruptions, etc. (that are also reported in the ICA database), have been excluded.

Methods

Methods for this indicator are the same as those used for "4.4. Economic losses due to climate-related extreme events" in Zhang et al.[19].

However, a minor change to previous years, is that the annual total insured economic losses have been adjusted for inflation, using the ABS 6401.0 Consumer Price Index Series for Australia (Series ID A2325846C). All amounts are now reported in 2019 dollars, allowing for a better comparison of the annual losses.

Caveats

Caveats for this indicator are the same as those for "4.4. Economic losses due to climate-related extreme events" in Zhang et al.[19].

Future form of indicator

An ideal form of this indicator would allow attribution of economic losses to events induced by climate change. However, such attribution is unlikely to be feasible. As such, it is not envisaged that this indicator will significantly alter.

4.2 Economic costs of air pollution

Data

Reported data are based on figures provided in the Australian Burden of Disease Study: impact and causes of illness and death in Australia 2015.[21] Data on the number of deaths, fatal and non-fatal burden attributable to air pollution in 2015 are reported in Table D2 (p. 167) of the report. Leading risk factor contributions to fatal and non-fatal burdens are reported in Figures D8-D11 (pp. 168-171) of the report.

Data on the Value of a Statistical Life Year (VSLY) in 2015 are derived, based on the Best Practice Regulation Guidance Note – Value of statistical life.[22] The note provides guidance on how officers preparing the cost-benefit analysis in Regulation Impact Statements should treat the benefits of regulations designed to reduce the risk of physical harm.

Methods

Data on the number of deaths, fatal and non-fatal burden attributable to air pollution in 2015 are reported in Table D2 (p. 167), of the report. Fatal burdens are measured in 'years of lost life' (YLL), non-fatal burdens are measured in 'years lived with disability' (YLD).

The estimate for the Value of a Statistical Life Year (VSLY) in 2015 is derived, based on the Best Practice Regulation Guidance Note – Value of statistical life.[22] The Office of Best Practice Regulation recommends that departments and agencies use the estimate of $151 000 for the VSLY (measured in 2007 dollars). CPI data for Australia (ABS 6401.0 Consumer Price Index Series for Australia, Series ID A2325846C) is then used to express these estimates in 2015. The method yields an estimate of the VSLY of approximately $182,000 measured in 2015 dollars.

Caveats

Estimators for the number of deaths, fatal and non-fatal burden attributable to air pollution for Australia vary significantly in the literature, as well as methods for exposure assessment and economic valuation with discounting. Therefore comparisons with other estimates of health costs should be made with caution.

Future form of indicator

Alternative estimators for the number of deaths, fatal and non-fatal burden attributable to air pollution for Australia could be used in future years. Australian Institute of Health and Welfare only seems to provide their report *Australian Burden of Disease Study: impact and causes of illness and death in Australia* every four years, so the next update will only be available in 2023.

Section 5: Public and political engagement

5.1 Media coverage of health and climate change

Data

Data for this indicator are the same as those used for "Indicator 5.1 Media coverage of health and climate change" in Beggs et al.[8].

Methods

Methods for this indicator are the same as those used for "Indicator 5.1 Media coverage of health and climate change" in Beggs et al.[8]. The search methods for the major newspapers in Australia were the same as we did last year except adding the data for 2019.

Caveats

Caveats for this indicator are the same as those for “Indicator 5.1 Media coverage of health and climate change” in Beggs et al.[8].

Future form of indicator

The indicator may include engagement in social media, eg, Facebook and Twitter, in future analysis.

5.2 Scientific engagement in health and climate change

Data

Data for this indicator are the same as those used for “Indicator 5.2 Coverage of health and climate change in scientific journals” in Beggs et al.[8]. We also include data on health and climate change grant applications provided by NHMRC.

Methods

Methods for this indicator are the same as those used for “Indicator 5.2 Coverage of health and climate change in scientific journals” in Beggs et al.[8]. The search methods were the same as we did last year except adding the data for 2019. We also did a preliminary analysis of the first 4 months of 2020 to capture scientific engagement in health and climate change related to the 2019/2020 summer bushfires.

Caveats

Caveats for this indicator are the same as those for “Indicator 5.2 Coverage of health and climate change in scientific journals” in Beggs et al.[8].

Future form of indicator

More in-depth review of the scientific publications, eg, adaptation or mitigation, to provide more contents of the studies, to identify gaps in research and directions for future research.

Contributions

YZ and PJB Co-Chair the *MJA-Lancet* Countdown. HLB leads Section 1; HB leads Section 2; MKL leads Section 3; ST leads Section 4; and AGC leads Section 5. Author contributions of indicators were as follows: PJB, 1.3; AM, 1.3, 3.1; HB, 2.1, 2.2, 2.3; ICH, 3.2; GGM, 3.2; ST, 4.1, 4.2; YZ, 5.1, 5.2. PJB, AM, and YZ drafted the manuscript and all authors contributed to revising it critically for important intellectual content. All authors provided final approval of the version to be published and agreement to be accountable for all aspects of the work. PJB, YZ, NW, AM, and AGC made substantial contributions to the overall conception and design of the work.

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Figure A1. Map of person-days of bushfire exposure in Australia in 2019 (Data Source: NASA)

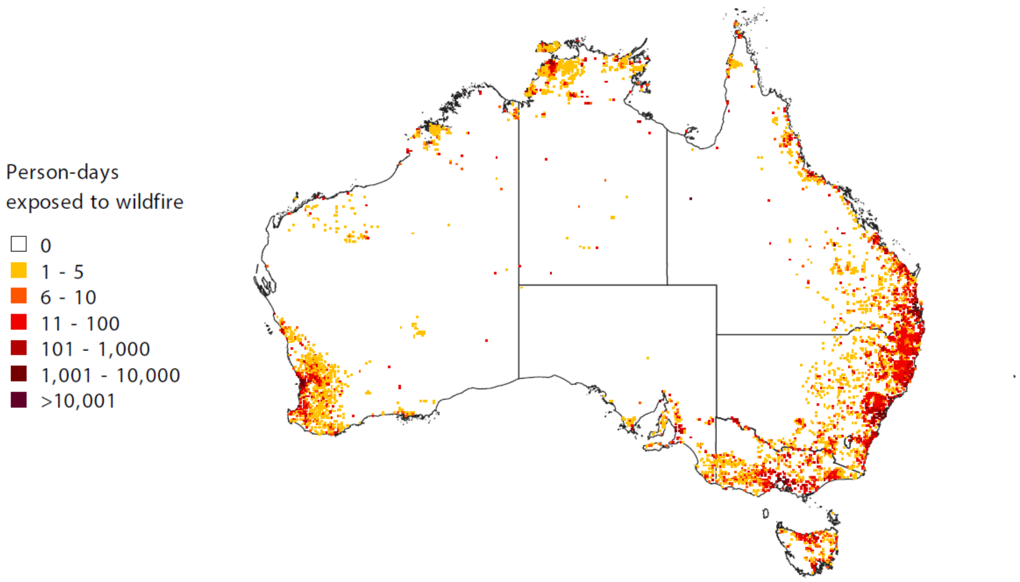

Figure A2. Australian Broadcasting Corporation online coverage of health and climate change topics, 2008-2019 (Data Source: Factiva (Dow Jones))