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To cite this article: Martina K Linnenluecke and Mauricio Marrone 2021 *Environ. Res. Lett.* **16** 125003

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LETTER

Air pollution, human health and climate change: newspaper coverage of Australian bushfires

OPEN ACCESS

RECEIVED

2 September 2021

ACCEPTED FOR PUBLICATION

3 November 2021

PUBLISHED

18 November 2021

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**Keywords:** climate change, air pollution, human health, Australian bushfires, newspaper coverage**Abstract**

We examine 512 Australian newspaper articles published over a five-year period (2016–2021) that report on air pollution due to bushfire smoke and resulting human health impacts. We analyze to what extent these articles provide information on the possible range of negative health impacts due to bushfire smoke pollution, and to what extent they report on climate change as a driver behind increased bushfire risk. A temporary surge in articles in our sample occurs during the unusually severe 2019/2020 Black Summer bushfires. However, most articles are limited to general statements about the health impacts of bushfire smoke, with only 50 articles in the sample (9%) mentioning an explicit link between bushfire smoke inhalation and cardiovascular and respiratory problems or increases in mortality risk. About 148 of the 512 articles in the sample (29%) established a connection between bushfire risk and climate change. We carry out a further keyword analysis to identify differences in reporting by Australia's two main publishing groups (News Corp Australia and Nine Entertainment), which shows that articles in News Corp Australia outlets offered the lowest climate change coverage. We suggest that more detailed communication strategies are needed to strengthen public preparedness for future impacts.

1. Introduction

The unprecedented magnitude of the 2019/2020 Australian Black Summer bushfires has confirmed warnings by scientists about increased bushfire risks due to both a decrease in rainfall and an increase in extremely hot temperatures that exacerbate bushfire conditions [1]. While bushfire risk is driven by a complex set of factors, including fuel load, fuel moisture, weather conditions and land management practices [2], several studies have concluded that the combination of climate variability and long-term climate trends has historically increased the risk of large and extreme forest fires occurring in southeast Australia [3–5]. Initial work has shown that the unusually intense 2019/2020 Black Summer bushfires were preconditioned by modes of tropical climate variability but exacerbated by anthropogenic climate change, which led to increases in the probability of extreme heat and the risk of severe fire weather [6, 7].

Bushfires not only have significant environmental, social and economic impacts [8] but also lead

to a substantial public health threat due to impacts resulting from air pollution and the inhalation of bushfire smoke; these impacts include premature mortality and aggravation of cardio-respiratory conditions [9]. A recent study has shown the extent of the health burden associated with the 2019/2020 bushfires: the fires led to over 400 excess deaths and over 3100 hospitalizations due to cardiovascular and respiratory problems [9]. In addition, bushfire-related health costs due to air pollution with PM_{2.5} likely amounted to AU\$1.95 billion [10] which is a substantial burden for the Australian economy. Bushfire risk in Australia is expected to increase further and substantially as a consequence of climate change [1, 6, 11]; however, there are concerns that the general public is largely unaware of the nexus between climate change, air pollution due to bushfire smoke, and human health impacts, and is consequently underprepared [12].

In response to the special issue call for papers and rising concerns about the health implications of bushfire risks, we investigate Australian newspaper

coverage of air pollution due to bushfire smoke and resulting human health impacts. The news media are an important channel for raising public awareness and perception of specific topics [13, 14], and have been found to directly impact public opinion on social and environmental issues [15]. The rationale for our study is to identify how the Australian public press has engaged in recent years with reporting on the health impacts due to bushfires and bushfire smoke pollution, and links to climate change as a driver behind increasing bushfire risk [12, 16, 17]. Findings from our analysis can also inform national and international indicators that track newspaper coverage of health and climate change [1, 12, 16, 18] to understand media engagement with these issues.

We find a temporary surge in newspaper articles on the nexus between bushfires, air pollution and human health during the peak bushfire activity over the summer of 2019/2020. However, most articles are limited to general statements about the health impacts of bushfire smoke (e.g. that members of the public should remain inside and avoid outdoor exercise), with only 50 articles in the sample (9%) mentioning an explicit link between bushfire smoke inhalation and cardiovascular and respiratory problems or increases in mortality risk. About 148 of the 512 articles in the sample (29%) established a connection between bushfire risk and climate change. We carry out a further keyword analysis to identify differences in reporting by Australia's two main publishing groups (News Corp Australia and Nine Entertainment), which shows that articles in News Corp Australia outlets offered the lowest climate change coverage. We seek to contribute to a more nuanced understanding of how risks to human health are reported in the media and conclude with suggestions for future research and recommendations for providing the Australian public with access to more detailed health information about the long-term risks of climate change.

2. Background

Despite a decline in the role of newspapers as information sources globally, newspapers and their websites remain a top source of news. A large-scale survey conducted by the Reuters Institute for the Study of Journalism [19] found that newspapers reached, on average, four in ten (44%) respondents weekly, ahead of TV news (33%) and social media (31%). There are certainly a wide range of information sources available, such that no single source determines the public's understanding of and response to any particular issue [20]. Variations in newspaper usage also exist; newspapers reached on average 30% of respondents in the Philippines, 36% in the U.S., 40% in the UK, 41% in Australia, 57% in Germany and 64% in Norway [19]. However, given the prevalence of newspapers in many countries, a significant body of

scholarship has focused on documenting newspaper coverage in areas such as public policy and public health [21], as well as risk and science communication [22, 23]. Climate journalism, defined as journalistic coverage of climate change, has become a growing field of study with increasing scholarly attention [24–26].

In Australia, newspapers have retained a significant role in the Australian media landscape, especially through their online editions. Research has shown that Australian newspapers have an important role in determining issues for public debates [27], and in framing the public's perception and interpretation of salient issues [28]. Data for the year 2020 show that the average print issue readership for News Corp's seven major titles was estimated to range between 2.0 and 2.9 million on any given weekday, and Nine Entertainment's combined print-only readership was estimated to range between 0.8 and 1.2 million [29, 30]. Monthly combined print/digital audiences are considerably higher, with News Corp's seven main outlets reaching 13 million and Nine Entertainment main outlets reaching 12 million readers over a four-week period [30]. Figures are based on readers aged 14+; the Australian population was about 25.7 million in 2020, which included approximately 21.0 million people aged 14 or over.

2.1. Media reporting on the nexus between bushfire risks, human health impacts and climate change

To date, there has been limited media coverage of the nexus between bushfire risks, human health impacts and climate change. Several studies of newspaper coverage in the U.S., Sweden and Australia have shown that the media largely focus on sensational, tragic and/or novel aspects when reporting on bush- and wildfires, while ignoring or underreporting longer-term societal or health impacts, such as the contributions of anthropogenic climate change to fire risk [17, 20, 31, 32]. Previous studies have documented the limited media coverage of links between air pollution and health outcomes [12, 16], and have also remarked that there is insufficient coverage of the increased bushfire risk due to climate change [17]. As reported in [16], annual Australian newspaper coverage of health and climate change actually decreased by 67% between 2008 and 2018, from an initial 200 articles per year during 2008–2010. Some temporary spikes in reporting on health and climate change coincided with the G20 meeting in Brisbane in 2014 and the extreme heat events that occurred during that summer [12]. An increase also took place in early 2019, likely due to the federal election campaign and Australia experiencing its warmest January on record at the time [16].

While the occurrence of extreme weather events generally prompts media attention to climate change [33, 34], the heightened attention does not necessarily translate into factual reporting about issues such as

health impacts or increased bushfire risk. A more in-depth media analysis of local, state and national mainstream media coverage in the aftermath of the 2009 Black Saturday Bushfires found that the media mainly focused on ‘blame games’ (i.e. attempts to attribute the blame for the bushfires, their intensity and inadequate bushfire fuel reduction policies to various actors, such as the state government and environmentalists), thus not allowing a more meaningful discussion of issues such as the impacts of climate change on weather conditions, the complexity of fire science, and the need to adapt to climate change [17].

2.2. Australian media and climate change

Prior research has pointed to a substantial lack of reporting on the impacts of climate change in the Australian press and has documented a proliferation of doubt and uncertainty around the science of climate change [35, 36]. The under- and misreporting of the topic of climate change has been attributed to several issues: The Australian media has historically held a close and almost symbiotic relationship with Australian politics [27]. Australia has seen an increasing political polarization of its two main newspaper companies, News Corp Australia and Nine Entertainment Co. (here referred to as Nine Entertainment) [37]. News Corp outlets are largely conservative-leaning, while Nine Entertainment outlets provide some ideological counterweight [35, 38, 39]. In addition, structural and regulatory issues have led to a high level of concentration of media ownership in Australia [27, 40]. Australia is now frequently cited as having one of the most highly concentrated media markets internationally (behind countries with state-owned media), which has led to concerns about media diversity and reliability [40]. Furthermore, journalistic tendencies to balance views might downplay scientific consensus and introduce views that are critical of or question the validity of scientific findings [41, 42].

While News Corp has Australian origins, the company became a dominant global media company.³

³ Nine Entertainment was created through a merger between Fairfax and PBL (Publishing and Broadcasting Limited) in 2018 and has retained a focus on the Australian media market. News Corporation (typically referred to as ‘News Corp’) was founded in 1980 by Rupert Murdoch as a holding company to consolidate his business interest (including News Limited, a news company that was originally founded in 1923 in Adelaide, Australia, with a minority investment from Rupert’s father Sir Keith Murdoch in 1949). In subsequent years, Murdoch substantially expanded News Corp and moved its headquarters to New York, eventually establishing News Corp as a global media empire with substantial cross-media ownership predominantly across the US, UK, and Australia [37]. After a series of scandals, the company was split into Twenty-First Century Fox (now Fox Corporation) and the present-day News Corp in 2013, with the Murdoch family retaining significant influence over both entities. Other companies are active in Australia, including Seven West and Australian community media but have a regional and limited reach.

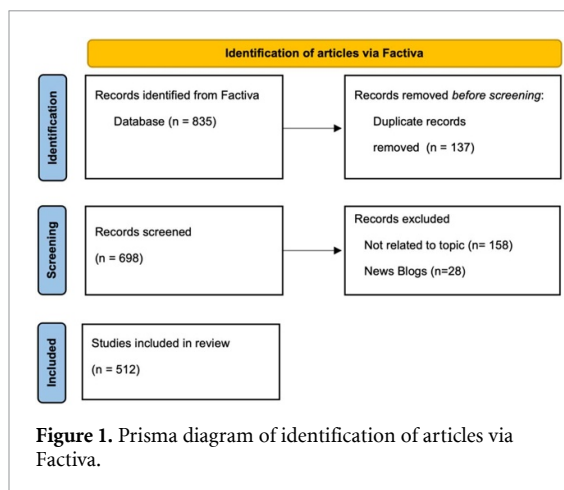
In the Australian news media segment, News Corp has ownership of about two-thirds of capital-city daily newspapers [43]. Due to its conservative leaning, News Corp supports coverage that favors fossil fuel interests and doubts the validity of climate science [35]. Biases in climate change coverage have not just been found in News Corp Australia outlets [44] but also in its US and UK newspapers [45, 46], and its US TV and cable news (Fox News) [47–49]. Studies found News Corp outlets to be generally ‘hostile’ towards reporting on climate science and concluded that denialists were given a prominent voice in the reporting [38, 50, 51]. There is also substantial evidence that mining industry interests have influenced Australian media coverage to secure public support for a ‘business as usual’ scenario that favors fossil fuels and limited action on climate change [35, 38, 52, 53]. Nine Entertainment outlets have, at times, argued for climate change action [38, 39]. However, the public controversy around Australia’s responsibility for climate change and the economic impacts of emission reduction legislation have largely crowded out reporting on other issues, such as the significant risks of climate change for the Australian population [14, 54].

The substantial media ownership concentration in Australia has provided a single corporation with considerable influence over which economic, political, and cultural topics are being reported [55]. However, these concerns are not limited to Australia: Given the global reach of News Corp, there has been substantial controversy about the impacts of News Corp on public opinion and global politics, with some commentators suggesting that political affiliations might have moved with the company’s bottom line [56].

The substantial concerns about Australian media ownership and the provision of reliable, accurate and independent news (not just on climate change, but on issues of public interest in general) formed the basis for a petition by former Australian Prime Minister Kevin Rudd, that called for a Royal Commission into media ownership, arguing that ‘media ownership is becoming more concentrated alongside new business models that encourage deliberately polarizing and politically manipulated news’ (see www.aph.gov.au/petition_list?id=EN1938). While a Royal Commission was eventually not established, the number of signatures (over 500 000) drew substantial attention to the petition and eventually prompted a Senate inquiry into the state of media diversity. The report is expected to be released in November 2021 (i.e. in the future at the time of writing).

3. Methodology

Here, we extend prior work by specifically examining newspaper coverage on the nexus between bushfire risks, human health impacts and climate change. The sample for the analysis consists of newspaper



articles from April 2016 to April 2021 (both online and print versions) that reported on air pollution due to bushfires and resulting human health impacts. The sample period covers newspaper reporting during multiple fire seasons, including the 2019/2020 Australian Black Summer Bushfires. To identify relevant articles for analysis, we used the digital newspaper archive, Factiva, which covers Australian national and regional newspapers. The database also contains options to search for Newswires and Press Release Wires, which we have excluded from the search to focus on newspaper article coverage.

Our sample includes articles from 13 newspaper outlets that publish national and regional news both in online and print formats. The selection of outlets follows the same coverage as prior analyses [16], and is based on three factors: (a) geographical diversity (b) circulation (c) regional and national coverage. We downloaded articles from the 21st of April 2016 to the 20th of April 2021. The rationale for this timeframe is to gather data that covers multiple fire seasons, including the 2019/2020 Australian Black Summer bushfires. The 27th of June 2019 is the date when the media warned of an early start to the 2019–2020 fire season following the release of the 2019 Northern Australia Seasonal Bushfire Outlook [57]. The final search string for the analysis is ('air quality' OR 'air pollution') AND (bushfire* OR smoke OR wildfire* OR fire OR fires OR 'bush fire' OR 'bush fires' OR 'wild fire' OR 'wild fires') AND health. Note, we first implemented a broader search term that did not yet narrow down the sample to articles that also mention climate change. We examine the reporting on climate change in the retrieved articles below (section 3.2).

The search yielded 835 articles for which we downloaded the full text, together with additional information (including the publishing date and relevant outlet). Subsequently, we filtered articles to exclude those that (a) had a high degree of similarity due to republishing (e.g. articles published as both online and print versions), or (b) that were not or only marginally related to the topic of interest (e.g. some

articles referred to fires other than the bushfires). The final dataset after data cleaning (see figure 1) consisted of 512 articles for inclusion. The full text of these articles (not including headings or author information) amounts to 556 pages of A4 text (Times New Roman 12pt, single-spaced).

3.1. Health messages

After extracting articles that cover air quality/air pollution as well as bushfires and health, both authors manually analyzed the content of the 512 articles to extract the exact message or information that was provided about the human health impacts arising from air pollution and poor air quality due to bushfire smoke. This was done by manually examining the full text of the articles and extracting passages of text for further analysis that referred to any health consequences of the bushfire smoke. Based on the manual analysis, we identified a list of health-related topics and then calculated the number of topic mentions per article in our sample. Results are reported in section 4.1 for News Corp and Nine Entertainment outlets.

3.2. Links to climate change

We also manually inspected each newspaper article to determine if and how the articles addressed the topic of climate change. During the analysis, it became apparent that the articles often used a particular framing for their reporting, with some articles not mentioning climate change but other topics, such as drought, greenhouse gases, or warming. We therefore grouped articles into five categories according to whether they mentioned (a) climate change, (b) drought, (c) carbon emissions, (d) warming, (e) greenhouse gas emissions. We assigned each newspaper article to these categories according to the terminology used. To introduce robustness to the analysis, both authors independently analyzed articles in a first step, before comparing findings. Overall inter-rater reliability [58] for all categories was an average of 0.93 across the five categories, with any discrepancies resolved through further discussion in a next iteration. Some articles were assigned to multiple categories as they covered multiple topics (e.g. climate change and greenhouse gas emissions). We report findings of this analysis in section 4.2.

3.3. Keyword analysis

In addition to the manual coding of the articles, we also implemented a computer-aided keyword analysis to determine which words were statistically salient in stories from one publishing group when compared to another [59]. Keyword analysis provides insights into the key topics, or messages, within a text and involves multiple steps, including (a) data pre-processing, and (b) the identification of the 'keyness' of words from the processed text. Keyness can thereby be understood as the salience of a word within a corpus of text, based

on the frequency of a word in one corpus relative to the frequency of the word across both corpora [60]. Here, we examine the keyness of words for the corpus of News Corp Australia articles and the corpus of Nine Entertainment articles. We also report on effect size, using a Dice coefficient, which is a well-known measure in information retrieval that essentially measures the similarities (or overlaps) between corpora of text. The coefficient ranges from 0 to 1, with a higher number indicating a greater similarity [61, 62].

We carried out the analysis in Python 3.0 using the package `gensim`. The first step, text pre-processing, aims to lower the complexity of the text while not affecting interpretability [63, 64]: it includes stopword removal (e.g. 'are' 'is' 'and'), lowercase conversion, and lemmatization; that is, converting words into their dictionary form, also known as a lemma (e.g. announced → announce, burned → burn) [65, 66]. A keyword analysis identifies words that appear more frequently in one corpus when compared to another using a log-likelihood analysis [60, 67]. Results are reported in section 4.3.

4. Findings

Figure 2 (upper panel) shows the distribution of the articles in our sample over time. A spike in newspaper coverage on bushfires, air pollution and human health impacts occurred during the Australian Black Summer Bushfires, specifically during the months of peak fire activity (November 2019–January 2020). Coverage dropped rapidly in February, likely due to a rapid drop in media attention once the main fire fronts were under control and a subsequent shift towards coverage of the unfolding COVID-19 crisis. We further report on the findings of our different analyses below.

4.1. Health messages

Table 1 shows the prevalence of health-related topics and their distribution in our sample, displayed as a metric that shows the average number of topic mentions per article for News Corp Australia outlets and Nine Entertainment outlets. As evident from the table, there are overall very limited references to the health impacts of the bushfires in articles published either in News Corp Australia outlets or Nine Entertainment outlets. Most articles only offer general statements (e.g. that exposure to bushfire smoke can enter the lungs and lead to respiratory problems, and that members of the public should remain indoors and avoid outdoor exercise).

Only 50 articles (9%) in our sample provided specific information on the link between bushfire smoke inhalation and health impacts, including cardiovascular and respiratory problems or increases in mortality risk. We see a larger coverage of these topics in articles published in Nine Entertainment outlets (table 1), which also focus more directly on health

outcomes due to air pollution as a result of bushfire smoke (see section 4.3).

The most significant difference which we identify is that articles in News Corp Australia outlets repeatedly compared bushfire smoke inhalation to smoking a certain number of cigarettes per day, a comparison which certainly provides a more vivid example for readers, but is also debatable [68]. An example is the following article published in the Daily Telegraph (emphasis added):

- *The air quality across NSW is so poor today it is the equivalent of smoking almost 30 cigarettes. Residents in the Northern Tablelands at Armidale had it worst as of 9am Tuesday, breathing in smoke that is equivalent of 28.2 cigarettes, according to the Department of Environment's Air Quality Index. Air in the Southern Tablelands equalled 27.35 cigarettes, in Sydney's north west it was close to 17 cigarettes while residents in the city's south west were breathing in the equivalent of 15.55 cigarettes.*

Reports about the equivalent of cigarettes smoked were virtually absent from articles in Nine Entertainment outlets. We found some isolated incidences of reporting in News Corp articles that downplayed the risks of smoke inhalation, for instance: '[Dr Tony Bartone reported that] current evidence on the long-term health effects of bushfire smoke was "thin"' [69].

4.2. Reporting on climate change

Of the 512 articles in the sample, 148 articles (29%) reported on a connection between air pollution due to bushfire smoke and climate change, drought, carbon emissions, greenhouse gas emissions, and/or global warming (figure 2, lower panel). Note that some articles fall into multiple categories as they refer to multiple topics and are counted towards all applicable categories. In November 2019, 35% of the published newspaper articles on air pollution, bushfires and health mentioned a connection to climate change. In December 2019, this rate substantially increased to 70% but dropped again in January to November levels.

As evident, there is overall a higher number of mentions of climate change and carbon emissions after the occurrence of the 2019/2020 Australian Black Summer Bushfires in late 2020 and 2021. This can, perhaps, be attributed to a heightened awareness of the risk of climate change after the occurrence of the 2019/2020 fires, but also coincides with the beginning of a new fire season. The analysis shows that, initially, the conversation focused, to some extent, on drought and climate change, but then shifted to a broader conversation around climate change and carbon emissions.

Table 2 lists the publishing group for each newspaper and the coverage of topics across the various outlets and shows that climate change as a topic was

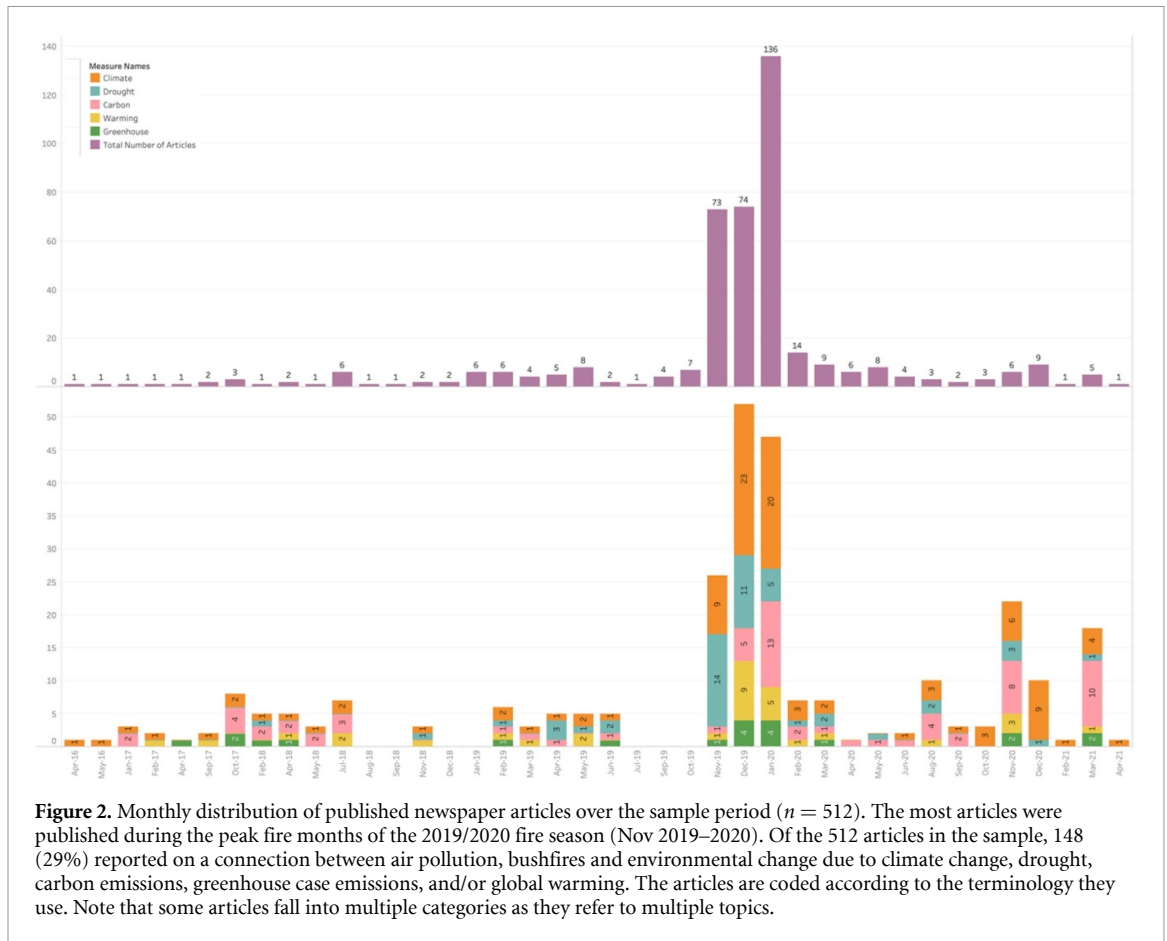


Figure 2. Monthly distribution of published newspaper articles over the sample period ($n = 512$). The most articles were published during the peak fire months of the 2019/2020 fire season (Nov 2019–2020). Of the 512 articles in the sample, 148 (29%) reported on a connection between air pollution, bushfires and environmental change due to climate change, drought, carbon emissions, greenhouse case emissions, and/or global warming. The articles are coded according to the terminology they use. Note that some articles fall into multiple categories as they refer to multiple topics.

Table 1. Health-related topic mentions per article.

Topic	Times mentioned per article	
	News Corp	Nine Entertainment
Respiratory	0.55	0.57
Indoors	0.51	0.30
Lung(s)	0.42	0.44
Exposure	0.41	0.40
Cigarettes	0.35	0.03
Mental health	0.18	0.17
Unhealthy	0.10	0.05
Hospitalization	0.06	0.12
Hospital admissions	0.04	0.09
Cardiovascular	0.02	0.09
Mortality	0.02	0.06

not equally represented across newspapers from the different publishing groups. News Corp Australia-owned outlets offered the lowest coverage on climate change, except for The Hobart Mercury and The Australian. Overall, articles published by News Corp linked bushfires to climate change 13% of the time, while Nine Entertainment Co linked these topics 31% of the time.

4.3. Salient words by publishing group

Tables 3 and 4 show the frequency and keyness (salience) of words in the News Corp and Nine Entertainment articles, respectively. Some words, such as

Queensland (News Corp) or Sydney (Nine Entertainment), can be explained by the circulation of the outlets in different regions (e.g. the Courier Mail, owned by News Corp, is published in Brisbane, Queensland, while the Sydney Morning Herald, owned by Nine Entertainment, is published in Sydney, New South Wales).

4.3.1. News Corp Australia

Articles in News Corp Australia outlets predominantly focus on events that were happening on the day (‘today’), such as wind changes that impacted the direction of the fire fronts (‘southeast’ and ‘southwest’). The articles also focus on firefighting efforts (e.g. ‘firefighters’ and ‘crew’), evacuations and road closures (e.g. ‘road’, ‘home’ and ‘evacuate’). We provide some text examples below (emphasis added):

- ‘The **wind** change is expected to bring a smoke haze in the **south-east today**’ [70]
- ‘Premier Annastacia Palaszczuk said the state was being plagued by “severe conditions” that did not help **crews** battling fires from the Gold Coast to Cape York.’ [70]
- ‘**Crews** have been working all night within both bush-fire zones to strengthen containment lines.’ [71]
- ‘Four **firefighting crews** and one caretaker remain on scene to battle the blaze.’ [72]

Table 2. Newspapers by publishing group and their coverage of bushfires, air pollution and human health, as well as their coverage of drought, carbon/greenhouse gas emissions, global warming and/or climate change. The last column reports the main topic focus and the number of articles that mention the topic. Some articles fall into multiple categories as they refer to multiple topics. Note that the table focuses on the two largest publishing groups, News Corp Australia, and Nine Entertainment Co. It does not include 80 articles from smaller outlets, including the West Australian and Canberra Times.

Publishing Group	Newspaper	Articles on bushfires, air pollution and human health	Articles that also cover climate change, drought, carbon/greenhouse gas emissions, and/or global warming	%	Main topic focus and number of articles mentioning the topic (in parentheses)
News Corp Australia	Courier Mail	34	6	18%	Drought (4)
	Herald Sun	62	7	12%	Climate change (4)
	Hobart Mercury	33	15	46%	Climate change (12)
	Northern Territory News	6	0	0%	N/A
	The Advertiser	12	1	8%	Climate change (1)
	Daily Telegraph	88	18	21%	Drought (8)
	The Australian	36	15	42%	Climate change (11)
	Subtotal	271	62	23%	Climate change (36) (13% of 271 articles)
Nine Entertainment	Australian	23	6	26%	Climate change (5)
	Financial Review				
	Sun Herald	6	5	83%	Climate change (3), Warming (3)
	The Age	46	15	33%	Climate change (14)
	The Sydney Morning Herald	86	36	42%	Climate change (28)
	Subtotal	161	62	39%	Climate change (50) (31% of 161 articles)

Table 3. Salient keywords in the sample of News Corp articles.

Top 10 salient words in News Corp articles			
Frequency	Keyness	Effect	Keyword
259	90.47	0.0048	Queensland
341	74.16	0.0063	Today
284	70.72	0.0052	Firefighters
240	69.97	0.0044	Road
95	69.19	0.0018	Southeast
171	68.99	0.0032	Crew
174	68.12	0.0032	Evacuate
78	64.15	0.0014	Southwest
459	63.80	0.0085	Home
480	60.74	0.0088	Wind

Table 4. Salient keywords in the sample of Nine Entertainment articles.

Top 10 salient words in Nine Entertainment articles			
Frequency	Keyness	Effect	Keyword
392	199.57	0.0141	Pollution
209	90.16	0.0076	Climate
90	83.59	0.0033	Coal
33	71.79	0.0012	AGL
428	70.61	0.0153	Sydney
76	58.80	0.0028	Cities
26	56.56	0.0009	HESTA
49	55.97	0.0018	Fossil
100	54.05	0.0036	Professor
78	48.23	0.0032	Fund

- ‘At 4.55am at Woodgate, **south** of Bundaberg, a bush-fire is burning near Woodgate **Road** and Woppis **Road**, and travelling towards Walkers Point **Road**, Woodgate. An **evacuation** centre is open at the Isis Cultural Centre.’ [73]
- ‘**Road** closure app: State and territory governments should include **road**-closure information on public apps.’ [74]
- ‘The Premier announced at a press conference this afternoon: the reason why we are doing it tomorrow ahead of Saturday is to make sure that Commissioner Fitzsimmons and all our personnel, all our agencies know that from tomorrow they will be subject to forced **evacuations**, **road** closures, **road** openings and anything else we need to do as a state to keep our residents and to keep property safe.’ [75]

- ‘Temperatures are set to reach up to 36 C in the **southeast today** and the Bureau of Meteorology has warned a **wind** change from northerly to **south-westerly**.’ [76]

4.3.2. Nine Entertainment

While there is also day-to-day reporting on bushfires in Nine Entertainment articles, the articles focus more explicitly on topics such as pollution and climate change (table 4). Pollution is typically mentioned in the context of air pollution due to bushfire smoke. Pollution levels (or readings) are also reported, often in conjunction with information about health consequences. Examples of articles that link reporting

on air pollution from bushfire smoke to health consequences include:

- ‘*Bushfires produce particulate-matter **pollution**—airborne particles that are small enough to enter and damage human lung tissue.*’ [77]
- ‘*Peak union and business groups have agreed a better system is needed to manage health and safety risks linked to dangerous **pollution** levels from bushfire smoke.*’ [78]

Climate is discussed in the context of climate change and climate policy. Examples include:

- ‘*In the state government’s strongest comments yet on the link between **climate** change and bushfires, Mr Kean said yesterday: “This is not normal and doing nothing is not a solution.”*’ [79]
- ‘*Australia’s extreme bushfire season was at least 30% more likely than a century ago because of **climate change**, and risk of a repeat will rise four-fold if global temperatures exceed a two-degree rise.*’ [80]

Other terms that are salient in Nine Entertainment outlets are coal, AGL (an Australian energy company) and HESTA (an Australian industry superannuation fund). Articles related to these key terms discuss the connection between fossil-fuel-related investments (‘fossil’, i.e. fossil fuels) and impacts in terms of climate change and human health. Examples include:

- ‘*A group of more than 200 medical professionals including former Australian of the Year Fiona Stanley have launched a campaign urging energy giant AGL to close its **coal**-fired power plants by 2030*’ [81]
- ‘*HESTA owns 0.4% of AGL, or \$23.8 million worth of shares.*’ [81]

Examples of articles on funding include articles discussing the set-up of a climate fund and funding for bushfire recovery:

- ‘*State will tap into **climate fund** to help communities*’ [82]
- ‘*The Victorian government also announced an \$86 million Victorian Bushfires Community Recovery Package, which is jointly funded under the Commonwealth-State Disaster Recovery Arrangements. The **funding** will cover mental health services, recovery programs, reconstruction and rebuilding, and local programs to build community resilience.*’ [83]
- ‘*Governments can take advantage of low interest rates to raise debt, although state governments and the federal government are now being forced to use budget surpluses for bushfire recovery **funds***’ [84]

Articles in Nine Entertainment outlets frequently cite expert opinions, as evidenced by the word ‘professor’ (referring to experts’ quotes included in the articles).

5. Discussion

The newspaper articles in our sample can certainly not be taken to be a representative sample of all media reporting in Australia. Nonetheless, newspapers are a major information channel for the public, and have repeatedly been found to be central to shaping awareness of issues such as health and climate change [18, 85, 86], but also the social and political discourse in a country [87]. As our analysis shows, the current newspaper coverage in Australia is not providing much in-depth or unbiased public health information that could support a comprehensive national health protection strategy [88]. We therefore see several questions for future research: (a) what other major channels influence public perception of bushfire risks and resulting human health impacts; (b) how can the reporting on topics such as climate change, bushfire risks, air pollution and health risks be strengthened; (c) can changes in media ownership and concentration improve the provision of reliable, accurate and independent news; and (d) what additional measures can be implemented to provide more nuanced health advice to the public, for example, on effective measures to protect against exposure to bushfire smoke?

Given that the news media provide a direct channel for raising public awareness and perception [13, 14], and for shaping public opinions and beliefs [15], research can further trace how newspaper coverage influences readers’ perceptions about future bushfire risks (not just in Australia but also in other regions prone to bushfires). As the influence of social media is increasing, it is likely that other information sources will influence public opinion, while the role of newspapers (especially print editions) might decrease. Future research can examine the role of various communication channels and their relative importance, also for prompting action on climate change more generally.

Our analysis has shown that the newspaper articles provided limited information on what the public should do to safeguard against health risks from exposure to bushfire smoke. Strategies such as remaining indoors can certainly reduce exposure, especially in relatively well-sealed rooms with appropriate air conditioning and air filters; however, they might not prove effective over longer periods of time (i.e. several days), and especially people in vulnerable population groups might need to consider additional steps (e.g. medication, face masks, or even a temporary relocation, if feasible) [88]. Future research can

explore media strategies for providing effective messages to the public, as well as the best communication channels and strategies to reach various audiences within the population.

The impact of media ownership and concentration in Australia is currently subject to a Senate inquiry into the state of media diversity (see above). The terms of reference for the inquiry are to examine (amongst other issues) the current state of public-interest journalism in Australia, the effect of media concentration, as well as barriers faced by small, independent and community news outlets. The regulation of media ownership has been sporadic and inconsistent in Australia, and has been subject to considerable debate, especially in light of media reforms in the US and the question of whether or not reforms serve a public interest [89]. While a more diverse media landscape might help to promote more balanced views, it might not necessarily improve risk communication or provide adequate health messages. Commentators have therefore proposed the formation of independent expert committees to develop accurate, evidence-based, practical, and consistent advice to the public [88]. In addition, there is an opportunity to strengthen the role of publicly funded broadcasters, which have a mandate to deliver science education and information in the public interest [54], but which have been subject to significant funding cuts in recent years. Future research can track the impact of policy recommendations from the Senate inquiry to see if they result in changes in media reporting, and further investigate international best practice for public risk communication.

6. Conclusion

We examined 512 Australian newspaper articles published over a five-year period (2016–2021) that report on air pollution due to bushfire smoke and resulting human health impacts. Our analysis indicates that Australian newspapers (especially those owned by News Corp Australia) are underreporting the health implications of bushfires and of an increased bushfire risk due to climate change, potentially leading to a limited recognition of future risks among the Australian public. Policymakers should consider implementing additional communication channels (e.g. via health professionals, public health websites, educational institutions, emergency response agencies) that provide clear and easily accessible information about health risks associated with bushfire smoke and poor air quality, and provide clear information on behavioral strategies that different population groups can implement to manage their health risks and to monitor for symptoms [88]. Access to such information will be invaluable to protect Australian public health in the future.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgments

The first author (MKL) acknowledges funding from the Australian Research Council.

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References

- [1] Yu P, Xu R, Abramson M J, Li S and Guo Y 2020 Bushfires in Australia: a serious health emergency under climate change *Lancet Plan Health* **4** e7–e8
- [2] Lindenmayer D B, Kooyman R M, Taylor C, Ward M and Watson J E 2020 Recent Australian wildfires made worse by logging and associated forest management *Nat. Ecol. Evol.* **4** 898–900
- [3] Abram N J, Henley B J, Gupta A S, Lippmann T J, Clarke H, Dowdy A J, Sharples J J, Nolan R H, Zhang T and Wooster M J 2021 Connections of climate change and variability to large and extreme forest fires in southeast Australia *Commun. Earth Environ.* **2** 1–17
- [4] Harris S and Lucas C 2019 Understanding the variability of Australian fire weather between 1973 and 2017 *PLoS One* **14** e0222328
- [5] Bowman D M, Williamson G J, Gibson R K, Bradstock R A and Keenan R J 2021 The severity and extent of the Australia 2019–20 Eucalyptus forest fires are not the legacy of forest management *Nat. Ecol. Evol.* **5** 1003–10
- [6] van Oldenborgh G J *et al* 2021 Attribution of the Australian bushfire risk to anthropogenic climate change *Nat. Hazards Earth Syst. Sci.* **21** 941–60
- [7] Wang G and Cai W 2020 Two-year consecutive concurrences of positive Indian Ocean Dipole and Central Pacific El Niño preconditioned the 2019/2020 Australian “black summer” bushfires *Geosci. Lett.* **7** 1–9
- [8] Bowman D M, Williamson G J, Abatzoglou J T, Kolden C A, Cochrane M A and Smith A M 2017 Human exposure and sensitivity to globally extreme wildfire events *Nat. Ecol. Evol.* **1** 1–6
- [9] Borchers Arriagada N, Palmer A J, Bowman D M, Morgan G G, Jalaludin B B and Johnston F H 2020 Unprecedented smoke-related health burden associated with the 2019–20 bushfires in eastern Australia *Med J. Australia* **213** 282–83
- [10] Johnston F H, Borchers-Arriagada N, Morgan G G, Jalaludin B, Palmer A J, Williamson G J and Bowman D M 2020 Unprecedented health costs of smoke-related PM 2.5 from the 2019–20 Australian megafires *Nat. Sust.* **4** 42–47
- [11] IPCC 2021 *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I. To the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press)
- [12] Zhang Y, Beggs P J, Bambrick H, Berry H L, Linnenluecke M K, Trueck S, Alders R, Bi P, Boylan S M and Green D 2018 The MJA–Lancet Countdown on health and climate change: Australian policy inaction threatens lives *Med. J. Australia* **209** 474

- [13] King G, Schneer B and White A 2017 How the news media activate public expression and influence national agendas *Science* **358** 776–80
- [14] Murali R, Kuwar A and Nagendra H 2021 Who's responsible for climate change? Untangling threads of media discussions in India, Nigeria, Australia, and the USA *Clim. Change* **164** 1–20
- [15] Bolsen T and Shapiro M A 2018 The US news media, polarization on climate change, and pathways to effective communication *Environ. Commun.* **12** 149–63
- [16] Beggs P J, Zhang Y, Bambrick H, Berry H L, Linnenluecke M K, Trueck S, Bi P, Boylan S M, Green D and Guo Y 2019 The 2019 report of the MJA–Lancet Countdown on health and climate change: a turbulent year with mixed progress *Med J. Australia* **211** 490–1 e21
- [17] Anderson D, Chubb P and Djerf-Pierre M 2018 Fanning the blame: media accountability, climate and crisis on the Australian “fire continent” *Environ. Commun.* **12** 928–41
- [18] Watts N *et al* 2020 The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises *The Lancet* **397** 9–15s
- [19] Newman N, Fletcher R, Schulz A, Andi S and Nielsen R K 2020 *Digital News Report* (Oxford: Reuters Institute for the Study of Journalism)
- [20] Cordner A and Schwartz E 2019 Covering wildfires: media emphasis and silence after the Carlton and Okanogan complex wildfires *Soc. Nat. Resour.* **32** 489–507
- [21] Xu Z, Ellis L and Laffidy M 2020 News frames and news exposure predicting flu vaccination uptake: evidence from US newspapers, 2011–2018 using computational methods *Health Communication* pp 1–9
- [22] Wakefield S E and Elliott S J 2003 Constructing the news: the role of local newspapers in environmental risk communication *Prof. Geogr.* **55** 216–26
- [23] McAllister L, Daly M, Chandler P, McNatt M, Benham A and Boykoff M 2021 Balance as bias, resolute on the retreat? Updates & analyses of newspaper coverage in the United States, United Kingdom, New Zealand, Australia and Canada over the past 15 years *Environ. Res. Lett.* **16** 094008
- [24] Bohr J 2020 Reporting on climate change: a computational analysis of US newspapers and sources of bias, 1997–2017 *Glob. Environ. Change* **61** 102038
- [25] Schäfer M S and Schlichting I 2014 Media representations of climate change: a meta-analysis of the research field *Environ. Commun.* **8** 142–60
- [26] Schäfer M S and Painter J 2021 Climate journalism in a changing media ecosystem: assessing the production of climate change-related news around the world *Wiley Interdiscip. Rev. Clim. Change* **12** e675
- [27] Speck D L 2010 A hot topic? Climate change mitigation policies, politics, and the media in Australia *Hum. Ecol. Rev.* **17** 125–34
- [28] O'Neill S J, Boykoff M, Niemeyer S and Day S A 2013 On the use of imagery for climate change engagement *Glob. Environ. Change* **23** 413–21
- [29] Morgan R 2020 Readership results for the year ending December 2020 (available at: www.roymorgan.com/industries/media/readership/readership-archive)
- [30] Australian Broadcasting Corporation 2021 How large is Rupert Murdoch's reach through News Corp in Australian media, old and new? (available at: www.abc.net.au/news/2021-04-14/fact-file-rupert-murdoch-media-reach-in-australia/100056660)
- [31] Morehouse B J and Sonnett J 2010 Narratives of wildfire: coverage in four US newspapers, 1999–2003 *Organ. Environ.* **23** 379–97
- [32] Berglez P and Lidskog R 2019 Foreign, domestic, and cultural factors in climate change reporting: Swedish media's coverage of wildfires in three continents *Environ. Commun.* **13** 381–94
- [33] Barkemeyer R, Figge F, Hoepner A, Holt D, Kraak J M and Yu P-S 2017 Media coverage of climate change: an international comparison *Environ. Plan C.* **35** 1029–54
- [34] Henderson-Sellers A 1998 Climate whispers: media communication about climate change *Clim. Change* **40** 421–56
- [35] Bacon W and Nash C 2012 Playing the media game: the relative (in)visibility of coal industry interests in media reporting of coal as a climate change issue in Australia *Journalism Stud.* **13** 243–58
- [36] Muenstermann I 2012 Australia's climate change, wind farming, coal industry and the 'big carbon plan': mine coal, sell coal, repeat until rich *Rural Soc.* **21** 231–49
- [37] Young S 2019 *Paper Emperors: The Rise of Australia's Newspaper Empires* (Sydney: NewSouth Publishing) p 672
- [38] Lidberg J 2018 Australian media coverage of two pivotal climate change summits: a comparative study between COP15 and COP21 *Pacific Journalism Review* **24** 70–86
- [39] Muller D 2017 Mixed media: how Australia's newspapers became locked in a war of left versus right (The Conversation) (available at: <https://theconversation.com/mixed-media-how-australias-newspapers-became-locked-in-a-war-of-left-versus-right-79001>)
- [40] Lidberg J 2019 The distortion of the Australian public sphere: media ownership concentration in Australia *Australian Quart.* **90** 12–20
- [41] Boykoff M T 2008 Lost in translation? United States television news coverage of anthropogenic climate change, 1995–2004 *Clim. Change* **86** 1–11
- [42] Boykoff M T and Boykoff J M 2004 Balance as bias: global warming and the US prestige press *Glob. Environ. Change* **14** 125–36
- [43] Holmes D and Star C 2018 Climate change communication in Australia: the politics, mainstream media and fossil fuel industry nexus *Handbook of Climate Change Communication* ed W L Filho, E Manolas, A M Azul, U M Azeiteiro and H McGhie (Berlin: Springer) pp 151–70
- [44] Mann M E and Toles T 2016 *The Madhouse Effect: How Climate Change Denial is Threatening Our Planet, Destroying Our Politics, and Driving Us Crazy* (New York: Columbia University)
- [45] Feldman L, Hart P S and Milosevic T 2017 Polarizing news? Representations of threat and efficacy in leading US newspapers' coverage of climate change *Public Underst. Sci.* **26** 481–97
- [46] O'Neill S J 2013 Image matters: climate change imagery in US, UK and Australian newspapers *Geoforum* **49** 10–19
- [47] Feldman L, Maibach E W, Roser-Renouf C and Leiserowitz A 2012 Climate on cable: the nature and impact of global warming coverage on Fox News, CNN, and MSNBC *Int. J. Press-Polit.* **17** 3–31
- [48] Feldman L 2016 Effects of TV and cable news viewing on climate change opinion, knowledge, and behavior *Oxford Research Encyclopedia of Climate Science* (Oxford: Oxford University Press) (<https://doi.org/10.1093/acrefore/9780190228620.013.367>)
- [49] Tandoc E C Jr, Takahashi B and Thomas R J 2018 Bias vs. Bias: how Fox News anchors discussed Pope Francis' stance on climate change *Journalism Pract.* **12** 834–49
- [50] McKnight D 2010 A change in the climate? The journalism of opinion at News Corporation *Journalism* **11** 693–706
- [51] Bacon W 2011 *A Sceptical Media Coverage of Climate Change in Australia* (Sydney: Australian Centre for Independent Journalism)
- [52] Jolley C and Rickards L 2020 Contesting coal and climate change using scale: emergent topologies in the Adani mine controversy *Geogr. Res.* **58** 6–23
- [53] Birkenfeld L 2020 *A Comparative Analysis of German and Australian Climate Change Coverage in Quality Newspapers: Framing a Political Election and an Environmental Disaster* (Ilmenau: Univ.-Verl. Ilmenau)
- [54] Debrett M 2017 Representing climate change on public service television: a case study *Public Underst. Sci.* **26** 452–66
- [55] Arsenault A H and Castells M 2008 The structure and dynamics of global multi-media business networks *Int. J. Commun.* **2** 43

- [56] Arsenault A and Castells M 2008 Switching power: Rupert Murdoch and the global business of media politics: a sociological analysis *Int. Sociol.* **23** 488–513
- [57] Withey A 2019 Bushfire season starts early across northern Australia due to ongoing hot, dry conditions (available at: abc.net.au/news/2019-06-27/bushfire-outlook-queensland-2019/11251150)
- [58] Krippendorff K 2004 Reliability in content analysis: some common misconceptions and recommendations *Human. Commun. Res.* **30** 411–33
- [59] Scott M and Tribble C 2006 *Textual Patterns: Key Words and Corpus Analysis in Language Education* (Amsterdam: John Benjamins Publishing)
- [60] Gabrielatos C 2018 Keyness analysis. Corpus approaches to discourse *Corpus Approaches to Discourse: A Critical Review* ed C Taylor and A Marchi (London: Routledge) pp 225–58
- [61] Maeder A, George M and Naveda B 2020 Identifying recent telemedicine research trends using a natural language processing approach *2020 Int. Conf. Artificial Intelligence, Big Data, Computing and Data Communication Systems (Icabcd) (IEEE)* (<https://doi.org/10.1109/icABCD49160.2020.9183816>)
- [62] van Eck N J and Waltman L 2009 How to normalize cooccurrence data? An analysis of some well-known similarity measures *J. Assoc. Inf. Sci. Technol.* **60** 1635–51
- [63] Denny M J and Spirling A 2018 Text preprocessing for unsupervised learning: why it matters, when it misleads, and what to do about it *Polit. Anal.* **26** 168–89
- [64] Uysal A K and Gunal S 2014 The impact of preprocessing on text classification *Inf. Process. Manage.* **50** 104–12
- [65] Jurafsky D and Martin J H 2008 *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition 2* (Upper Saddle River, NJ: Pearson) p 1032
- [66] Schütze H, Manning C D and Raghavan P 2008 *Introduction to Information Retrieval* (Cambridge: Cambridge University Press)
- [67] Marrone M and Hammerle M 2018 Smart cities: a review and analysis of stakeholders' literature *Bus. Inf. Syst. Eng.* **60** 197–213
- [68] Muller R A and Muller E A 2015 *Air Pollution and Cigarette Equivalence* (available at: <http://berkeleyearth.org/air-pollution-and-cigarette-equivalence/>)
- [69] Waters C, Fagan J and Frost A 2020 Heavy downpour may worsen conditions in fire-ravaged towns *Herald Sun*
- [70] Chamberlin T, O' Neal D and Cockburn G 2019 It's about to fire up. *Courier Mail* 6
- [71] O'Neal D, Cockburn G, Williams E and O' Flaherty A 2019 Premier lauds new disaster recovery facility *Courier Mail*.
- [72] O'Neal D, Cockburn G, Chamberlin T, Kerr J and French T 2019 70 blazes: perfect firestorm as weather conditions collide *Courier Mail*.
- [73] O'Neal D, Cockburn G, Williams E and O'Flaherty A 2019 Ambassador's message of support as US plane flies in *Courier Mail*.
- [74] The Advertiser 2020 Royal Commission says these are the key changes needed *The Advertiser* p 14
- [75] Snowden A, Schipp D, Lunn S and Gair K 2020 Evacuation centres close ahead of fire storm *The Australian*
- [76] O'Neal D, Cockburn G, Chamberlin T, Kerr J and French T 2019 Aquatic centre cleared in latest fire alert *Courier Mail*
- [77] Fowler M, McCauley D and Eddie R 2020 Haze set to stay until Friday as city dwellers rush to buy masks *The Age*
- [78] Patty A 2020 Unions and business urge better approach to air pollution health risk *The Sydney Morning Herald*
- [79] Smith A and Crowe D 2019 This is not normal *The Sydney Morning Herald* p 1
- [80] Hannam P 2020 Extreme fires a third more likely: study *The Sydney Morning Herald* 13
- [81] Grieve C 2021 High-profile doctors mount campaign against AGL, HESTA to shutter coal plants *The Sydney Morning Herald*
- [82] Hannam P 2019 State will tap into climate fund to help communities *The Sydney Morning Herald* p 12
- [83] Wootton H and Baird L 2020 Vic death toll rises, smoke disrupts tennis *The Australian Financial Review* 5
- [84] Wiggins J 2020 How trains are helping Australia rethink cities *Australian Financial Review*
- [85] Boykoff M T 2011 *Who Speaks for the Climate? Making Sense of Media Reporting on Climate Change* (Cambridge: Cambridge University Press)
- [86] Carvalho A and Burgess J 2005 Cultural circuits of climate change in UK broadsheet newspapers, 1985–2003 *Risk Anal.* **25** 1457–69
- [87] Gavin N T 2009 Addressing climate change: a media perspective *Environ. Polit.* **18** 765–80
- [88] Vardoulakis S, Jalaludin B B, Morgan G G, Hanigan I C and Johnston F H 2020 Bushfire smoke: urgent need for a national health protection strategy *Med J. Australia* **212** 349–53 e1
- [89] Jolly R 2007 Media ownership deregulation in the United States and Australia: in the public interest? (available at: www.rsfedds.aph.gov.au/binaries/library/pubs/rp/2007-08/08rp01.pdf)