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Understanding the challenges in bushfire map use and effective decision-making amongst the Australian public

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ABSTRACT

Background. Bushfire maps are an important tool in public decision-making during bushfire events; however, they are understudied in the global literature. **Aims and methods.** This study uses qualitative data from three locations in Australia in 2022 and 2023 to understand how maps are used during a bushfire event by members of the public. **Key results.** The results show that maps provide an array of information during bushfires including information on the bushfire itself, traffic, and the weather. This information helped individuals form risk assessments. However, the trustworthiness and credibility of maps were questioned by participants owing to a lack of perceived timely updates and inconsistency between information sources. Participants expressed a desire for maps to convey more detailed information on the bushfire and related events; however, prior evidence suggests that people may misinterpret complex maps. **Conclusions.** This study found that it is important that bushfire maps are updated in a timely manner, clearly display their time and date of issue, and include relevant information, with an understanding that including too much or complex information may be problematic for comprehension. **Implications.** These findings have implications for how bushfire maps should be designed and disseminated to the public to ensure comprehension.

Keywords: Australia, bushfire, bushfire maps, hazard response, qualitative, wildfires.

Introduction

Bushfires (also referred to as wildfires) are a significant threat to lives and livelihoods throughout Australia and the world, with climate change increasing their intensity and frequency (IPCC 2021). The Australian Black Summer bushfires in 2019–2020 were unprecedented in their scale, with at least 33 deaths and over 3000 homes destroyed (Jalaludin and Morgan 2021). Minimising the negative impacts of bushfires generally requires effective, proactive decision-making and early departure if deciding to evacuate. Within Australia, individuals may choose to evacuate or remain and defend their property. Key factors that influence their decision-making are the perception of imminent threat and the receipt of official warnings (Strahan *et al.* 2018). Bushfire maps used during a bushfire event can help individuals better understand their risk level as they provide spatial cues and visual information (Bowser and Cutter 2015; Stieb *et al.* 2019). Despite this, research on bushfire map use is limited. This study therefore seeks to further our understanding of how individual community members engage with, and use, maps during a bushfire event to aid improvements to map design effectiveness.

Existing studies have highlighted the importance of maps during bushfire events. A study by Whittaker *et al.* (2021) on the Australian Black Summer bushfires in New South Wales found that approximately half of the participants used bushfire prediction maps (the first time they had been issued by the state) to inform their decision-making and plan their evacuation, while a 2015 study of five separate wildfire-affected populations in the United States found that 62% of residents used various maps to get information

(Steelman *et al.* 2015). Maps can be more effective than text messages during bushfire events in improving comprehension of the event (Cao *et al.* 2016) and have been identified as an effective communication tool in other hazards such as floods (Houston *et al.* 2019) and volcanic eruptions (Lavigne *et al.* 2017). However, studies that have focused on the design and comprehension of hazard maps have highlighted aspects of their content and format that impact their effectiveness (Cao *et al.* 2016, 2017; MacPherson-Krutsky *et al.* 2020; Lindell 2020; Clive *et al.* 2021). For example, maps with many incident and hazard icons, or with large areas highlighted, can make it challenging for individuals to differentiate between hazard and risk and can result in misinterpretation of the size and location of the hazard (Monmonier 1997; Ruginski *et al.* 2016; Padilla *et al.* 2017).

Bushfire maps

Bushfire maps are produced by a range of organisations, including fire services, local authorities, third-party mobile applications (Kulemeka 2015) and in some cases, members of the general public (Santana *et al.* 2021). As a result, the information they convey can differ substantially. Owing to the frequency of bushfires in Australia, bushfire maps and bushfire information are communicated regularly to the public. However, different types of bushfire maps are used by different organisations. Bushfire spread prediction maps have been produced by some of the states and territories. These maps show the area that has been burned, the potential path of the bushfire, and the locations of ember spread. This assists the public in knowing whether they are directly at risk and allows them to track the likely progression of the bushfire. New South Wales (NSW) and the Australian Capital Territory (ACT) issued bushfire spread prediction maps during the 2019–2020 Black Summer fires, an example of which is shown in Fig. 1. In Fig. 1, the grey area represents the current burnt area, the solid red area represents the potential fire spread area, while the transparent red area represents the area at risk of potential ember attacks. These maps have received positive feedback from the public (Dootson *et al.* 2022*b*). In contrast, incident maps, which are issued as standard practice in Australia, are simpler and show areas that are currently under threat from bushfires. Most use a polygon (or 'fire footprint' for the case of NSW) to indicate the area that is under a specific warning level.[1] The warning level indicates to the public what action they should take. The Tasmanian state authorities use incident maps, as shown in Fig. 2. The design of incident maps differs slightly between states; however, it is standard practice for all Australian states to produce incident maps that detail where the risk is located and what level of warning the area is under.

Despite the additional information conveyed in bushfire spread prediction maps, Cao *et al.* (2017) found that most individuals in their Australian study did not completely trust modelled bushfire spread predictions and relied on their own risk assessments rather than those communicated by the authorities. These individuals, deemed 'self-reliers', prefer to acquire information from multiple sources during a bushfire event, including maps, and seek frequent updates on wind direction, bushfire intensity and bushfire boundaries, amongst other things.

When creating hazard maps that portray uncertain information, such as predicted bushfire spread, there is also evidence that map readers may miscalculate risks and make inaccurate risk assessments (Ruginski *et al.* 2016; Padilla *et al.* 2017). Even the 'self-reliers' were reported to make errors when reading bushfire maps (Cao *et al.* 2017). The other group that Cao *et al.* (2017) identified were named 'advice followers'. These individuals made up a small minority of their sample (3/21) and chose to prioritise and act on official guidance.

There have been calls by natural hazard researchers for more research on how hazard maps should be designed to maximise comprehension (Dallo *et al.* 2020; Lindell 2020). The present study therefore seeks to fill an important gap in the literature and better understand how people used maps in recent bushfire events. This will offer insight into the role maps play in decision-making and how bushfire maps can be designed to increase their effectiveness.

The Protective Action Decision Model (PADM) is widely used in hazard studies to understand how individuals make decisions when faced with natural hazards and risks. It is a multi-stage model that includes both pre-decisional and decisional processes (Lindell and Perry 2012; Lindell 2018). The present study uses the PADM framework to better understand the role of maps in decision-making in bushfire events. Within the model, information sources (such as maps), environmental cues, social cues, and warning messages all contribute to the perception of risks. The processing of information from these external sources is referred to as pre-decisional processes and these require that an individual receives, pays attention to, and comprehends information before they act on it. Individuals must perceive a threat or risk and hold certain beliefs about the effectiveness of protective actions before they decide how to respond. Bushfire maps can act as an important external information source that can help increase comprehension and risk perception by providing clear visual and spatial cues related to risks. However, as discussed above, the design and dissemination of bushfire maps will affect how well an individual receives and comprehends the information they convey.

The PADM was developed based on decades of previous hazard studies but was not designed specifically for the

[1] https://alert.tas.gov.au/know-your-warnings

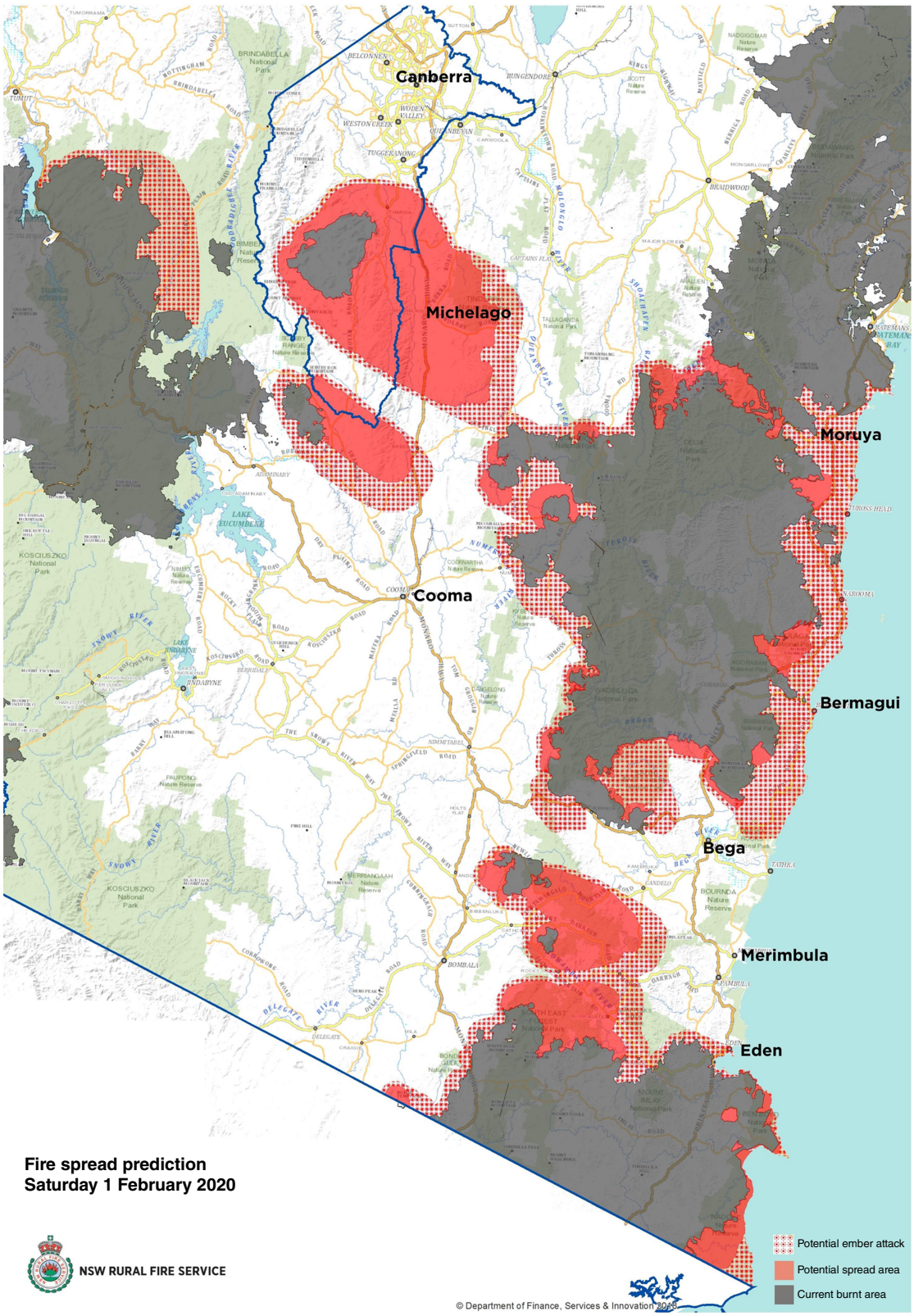

Fig. 1. Fire spread prediction map from ACT Emergency Services Agency, 2019. Source: ACT Emergency Services Agency (2020).

Fig. 2. Fire incident map from TasALERT, 2023. Adapted from: ABC News (2023).

Fig. 3. Map displaying the three selected study locations.

Australian context. In their study, Strahan and Watson (2018) therefore proposed an adaptation to the PADM based on their findings that Australians are more likely to take protective actions that may help them defend their property in a fire, such as obtaining personal protective gear and clothing and reducing property vulnerability. Such actions may make individuals less likely to evacuate as they believe they can successfully and safely defend their property. Therefore, they argued that an additional variable 'long-run hazard adjustments', which captures the long-term behaviour of individuals preparing for a hazard event, should be included in the PADM when it is applied to Australia as these adjustments directly affect behaviour and decisions on evacuation.

Methods

This study used in-depth semi-structured interviews to explore how residents of three locations across Australia comprehended, perceived, and acted on bushfire maps during previous bushfire events. This project was reviewed and approved by RMIT's Human Research Ethics Committee (25509).

Study location

Study participants resided in Victoria, the Australian Capital Territory and New South Wales, or Tasmania. Each state or territory in Australia produces official bushfire maps with differing levels of detail. All jurisdictions issue incident warning maps; fire prediction maps are issued infrequently. ACT/NSW was selected because it issued fire prediction and ember spread maps during the 2019–2020 fires, which allowed us to test their use against the more commonly issued incident warning maps of Victoria and Tasmania. The research is part of a larger project that has been conducted in partnership with Natural Hazards Research Australia (NHRA). The project's steering group, which

included state agency experts in warnings and fire predictions, assisted in identifying specific communities within these states that had recently experienced a bushfire event. Cardinia Shire in Victoria, Southern ACT/Snowy Monaro Regional Council in NSW and the Huon Valley in Tasmania were selected. The locations are highlighted on the map in Fig. 3. More detail of the study location selection process can be found in Kuligowski *et al.* (2023).

Recruitment

Recruitment materials were co-designed with local councils and fire agencies and were disseminated via local media (radio and newspapers), social media, emails from local council and fire agencies, letter drops, posters, and in-person community meetings, which were attended by the project team. Interview participants were also asked to let others in their network know about the project, thereby using snowball sampling. All recruitment materials encouraged prospective participants to contact the research team or complete an online Qualtrics survey to express their interest in participating. The Qualtrics survey provided an overview of the research, including the timing and locations of interviews, and asked the following two screening questions:

(1) Can you recall a recent experience (maybe in the last 3 or 4 years) where you were in an area threatened by a bushfire?
(2) Are you 18 years or older?

If the participant answered yes to both questions, they could opt to use an online booking system or request that a team member contact them to book their interview.

In total, 94 people were interviewed, either in person or online. The interviewees were evenly distributed among all three locations (i.e. Cardinia Shire (n = 33), Huon Valley (n = 32), Southern ACT and Snowy Monaro, NSW (n = 27)).

Interviews

Each interview lasted approximately 1 hour. Prior to commencing each interview, participants were asked to complete a short questionnaire on their demographic characteristics, past experiences of bushfire, perception of bushfire risk, and familiarity with maps. A copy of this questionnaire is shown in Supplementary Material S1. During the interview, participants were asked questions on their recent bushfire experience, including the cues they received, the maps they used, the map use challenges they experienced, and their decision-making. The research team did not restrict interview discussions to bushfire maps but allowed participants to talk about all the different types of maps they used during the bushfire. The interview guide used is provided in Supplementary Material S2.[2]

Analysis

Almost all participants agreed to audio recording of their interviews, and for those who did not, detailed notes were taken. The audio recordings were transcribed and coded using Nvivo. Codes were initially developed based on the interview guide and then revised after reviewing the transcripts to include additional topics that were discussed by participants. To ensure intercoder reliability, recommendations by Cofie *et al.* (2022) were followed. Further analysis of the data assigned to each code allowed the research team to identify themes, which are discussed in the following section. Team members also identified archetypal quotes from participants that explained and illustrated these themes.

Results

Descriptive statistics

Table 1 shows the demographic characteristics and previous bushfire experience of the interviewees, gathered from the pre-interview questionnaire. Across the sample, 50% of participants identified as men and 50% identified as women. However, the percentages differed between locations, with 34% of participants identifying as female in NSW/ACT and 63% identifying as female in Tasmania. None of the participants were aged between 18 and 34 and only 10% of participants were aged 35–44 years old. Those aged 55–64 made up the largest proportion of the sample, indicating that the sample is skewed towards older participants. Fifty percent of the participants were frequent users of any type of map, including those not specifically related to bushfires. When asked whether they, or a member of their household, were a current or previous member of an emergency services agency, 39% of the sample indicated yes. In NSW, this proportion was the largest, at 67%. Most of the sample population (76%) had undertaken mitigation actions prior to a recent bushfire experience, for example installing sprinklers or a water pump.

Qualitative analysis

Three overarching themes emerged from the analysis: accessing maps as a key source of information, why people used maps, and the challenges associated with using and comprehending bushfire-related maps. These themes are expanded on below.

[2]The interview guide was structured in two parts. Part 1, where interviewees were asked about their experiences with a recent fire, is the focus of this analysis. The questions included in Part 2 asked participants to provide their perspectives on two to three different maps showed to them during the interview. Part 2 is included in Supplementary Material S2 for completeness; its results will be presented in future publications.

Table 1. Interview participant characteristics.

	Entire sample		Victoria		NSW/ACT		Tasmania	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Gender								
Female	47	50	17	52	10	34	20	63
Male	47	50	16	48	19	66	12	38
Age (years)								
18–24	0	0	0	0	0	0	0	0
25–34	0	0	0	0	0	0	0	0
35–44	9	10	2	6	3	12	4	13
45–54	12	13	2	6	3	12	7	22
55–64	34	37	12	36	11	44	11	34
65–74	25	27	10	30	6	24	9	28
75 or older	11	12	7	21	2	8	1	3
Education level								
Left school before Year 10	2	2	0	0	0	0	2	6
Completed High School Year 10	10	11	3	9	2	7	5	16
Completed High School Year 12	7	8	4	12	1	4	2	6
Technical and Further Education (TAFE) qualification	18	20	5	15	9	33	4	13
Bachelor's Degree	31	34	11	33	9	33	11	34
Postgraduate Degree	24	26	10	30	6	22	8	25
Frequency of prior map use								
Daily	50	54	13	39	19	70	18	56
Weekly	27	29	14	42	7	26	6	19
Monthly	8	9	3	9	1	4	4	13
Yearly	2	2	1	3	0	0	1	3
Never	5	5	2	6	0	0	3	9
Emergency Services involvement								
Yes	39	42	12	36	18	67	9	28
No	53	58	21	64	9	33	23	72
Mitigation before the fire								
Yes	76	84	27	84	21	78	28	88
No	15	16	5	16	6	22	4	13

Accessing maps as a key source of information

The majority of participants, 92%, used maps during their recent bushfire experience. Maps from several platforms were referenced. These maps displayed information such as bushfire spread predictions, bushfire hotspots, lightning strikes, and weather information. Google Maps was mentioned frequently, often as a resource to monitor traffic conditions. One participant in Victoria mentioned using an AusNet[3] map to follow power outages.

How and which maps were accessed and used differed between the three study locations. In Victoria, most participants accessed maps via VicEmergency, which is the official

[3]AusNet is an energy delivery service in Australia: https://www.ausnetservices.com.au.

state government mobile application and website for emergency warnings, or via the Country Fire Authority (CFA) website. Facebook was also mentioned several times by the Victorian participants.

> The ones that I saw on Facebook were ones that people had screenshotted off the VicEmergency and shared to Facebook for those that didn't have the VicEmergency app. (VIC, 8)

In NSW/ACT, most of the respondents also used official mobile applications and websites to access maps including 'Fires Near Me', which was the NSW government online application (now known as 'Hazards Near Me'). Several NSW/ACT participants accessed non-official maps on a website,[4] which is a platform developed in 2019–2020 by an Australian start-up company. This map provides additional fire-relevant information such as wind direction. This website received positive feedback from those who used it.

> There is another website I think that I came across called bushfires.io [sic]. Have you ever seen that? It's a really good website; it has the wind and everything. (NSW/ACT, 4)

> That's what I was looking at – Fires Near Me and more bushfire.io, which is much, much, much more effective. (NSW/ACT, 18)

Individuals who lived in NSW but were near the border of Victoria downloaded both the Fires Near Me and VicEmergency mobile applications to monitor the bushfire spread because the mapped information in each app stopped at the state border.

> I was keeping an eye on the Fires Near Me app as well, and then when the Victorian ones got bad, I downloaded the Victorian app, and then Canberra set fire so I downloaded their app and tried to keep track of what their fires were doing. (NSW/ACT, 28)

In Tasmania, participants accessed the Tasmanian Fire Service website for information and maps on the bushfire or used the TasALERT mobile application. Maps accessed via in-person community meetings in Tasmania were also spoken about positively by participants:

> They had lovely maps on the wall … They were fantastic … They showed the advance of the fire, there was a progression of maps showing the direction of the fire, the intensity of the fire, they showed where the fire brigade were putting up barriers. (TAS, 5)

Across all three locations, participants talked about how community meetings helped them understand the bushfire situation and the information that was conveyed on maps.

> There were daily community meetings after that point, so we probably got a better understanding after we'd had a couple of those sessions where they explained how the maps were being updated because … I guess you expect them to use like real-time updates on the map … once we'd had that explained to us a few times it was like, 'Okay. Well, you can't…'. (VIC, 18)

Some mapping platforms were used by residents in multiple states. These included the Windy App, a third-party weather mobile application that can be downloaded on phones, the Digital Earth Australia (DEA) hotspots map (a national bushfire monitoring system produced by Geoscience Australia in collaboration with Digital Earth Australia), and the Bureau of Meteorology (The Bureau or BOM) maps.

Across all participants, maps were only one of multiple sources of information that they received and used during the bushfire event. Radio communications, local media, neighbours and friends, social media posts, and conversations with emergency service members were all identified as sources of information by participants.

Why people used maps

During the bushfire events, maps were used for multiple purposes including self-localisation and gathering information on the bushfire itself, wind direction, burnt areas and traffic.

Many participants used maps for self-localisation. Through the spatial data provided by the map, they were able to locate themselves in relation to key events and locations, such as the bushfire hotspots. Self-localisation helped individuals assess their risk, with a participant in Tasmania noting that:

> … the best map that I actually started looking at was at the DEA hotspot map of Australia and that was fantastic because I could really drill in and actually see where the fires are in relation to our property because we were never really sure about how close they were, and wind direction, and of course fires can move pretty quick. (TAS, 13)

Maps were also used to gather information about the bushfires, such as their boundaries and active areas, although the level of information that was provided by maps differed depending on the study location. For example,

[4] https://bushfire.io/.

the NSW/ACT participants often mentioned reviewing fire prediction maps similar to that shown in Fig. 1, where they could see the predicted path of the bushfire. Different types of maps were available to those in Victoria and Tasmania.

> The RFS [Rural Fire Service] was putting out predictive maps to the public. They did what I thought was a pretty damn good job actually. (NSW/ACT, 17)

Maps from third-party mobile applications, such as the Windy App, and from weather agencies, such as the BOM, were used to gather information on wind direction. According to participants, they could then identify in what direction the bushfire would move.

Participants relied on maps to provide information on what they should do next, including to where they should evacuate and what roads to travel on. They also used them to identify the alert or warning level for different locations.

> I used those maps to watch how fast it [the fire] was coming, how big it was getting, were we in danger, where to evacuate. (TAS, 8)

Owing to the number of different maps available from different sources, it was common for participants to cross-reference maps to better understand their risk. For example, participants would combine information from maps showing wind direction and those showing bushfire locations to develop their own understanding of bushfire direction.

> I get notified if there's a fire within 50 or 60 km of me, and I look at it, and then I look at the Bureau of Meteorology and see where the wind's coming from, and then I look back at a fire map, and I spent a lot of time on the fire maps actually and I spent a lot of time checking it against the wind and the predicted wind direction. (NSW/ACT, 12)

A few individuals noted taking screenshots of maps so that they could compare the changes in burnt areas as maps were updated. This form of 'map hacking' allowed them to increase the capabilities of the map beyond those provided by the mapmaker.

Some participants also reported using maps to confirm physical cues that they had already witnessed.

> By the time I got home, I could actually see the smoke from my backyard, so I looked on the emergency app … and I looked at the wind directions. (VIC, 3)

Maps were used at differing frequencies throughout the bushfire event. Most often, maps were used when the bushfire had not yet spread to the participants' locations, when the bushfire was moving quickly, when they were under Watch and Act or Emergency Warning conditions, and/or when there was smoke in the area.

> I was checking it regularly. I was conscious of the fact it [the fire] was getting closer. (NSW/ACT, 11)

Many participants used maps on a frequent basis, i.e. as many as 20–50 times per day (NSW/ACT, 2). A participant in NSW/ACT described their frequent map usage in this way:

> Yeah, we were kind of living off them really. You'd see something or you'd go around to a neighbour's place and see it from a different angle, and you'd go and check the app again, just trying to get our heads around exactly what was happening – we were really living off it. It was used more – those apps were used more than the phone feature of the phone over those days. (NSW/ACT, 27)

Those who were checking maps frequently expressed their understanding of how fast bushfires could move and therefore their desire for regular information. One participant described themselves as becoming 'obsessive' (VIC, 17) about obtaining frequent updates.

Although the vast majority of participants used bushfire maps on a frequent basis, a minority described limited map usage during their bushfire experience. Their reasons were: being too busy undertaking firefighting efforts, not having the proper device to access the maps, and being unable to use a device to access the maps. Some felt that maps were not needed in their situations, whereas others chose to rely on their local knowledge and/or they could physically see the bushfire and therefore did not need the information from the map.

The challenges associated with bushfire maps

Participants identified a number of challenges associated with using bushfire maps. These included a lack of timely information, their accessibility and missing or inconsistent information. In some circumstances, these factors reduced participants' trust in maps.

Timely information was important to respondents who wanted to know the current state of affairs. The lack of perceived timely information from certain mapping platforms was particularly apparent to participants who were using multiple platforms at once. In the ACT and Victoria, it is protocol that official maps are time-stamped. For both NSW and Tasmania, the warning icons and messages display the time of update, or time since the update; however, the maps are not always time-stamped.

> I felt like if I went to the Windy App, that was really current, and then sometimes when I'd be looking at the Fires Near Me app or the Emergency Services one, I'd be like, 'Is this old? Has this actually changed since this had

been updated or is this up-to-date?' I do think I had that feeling about 'How much can I trust this information?' (NSW/ACT, 27)

Different maps (i.e. incident warning maps and maps available on third-party mobile applications) updating at different times created inconsistencies between information sources and led to confusion amongst participants, especially when a map did not clearly state when it was last updated. One participant stated that:

The difference in different maps doesn't lead to trust. (NSW/ACT, 14/15 – a couple interviewed together)

Maps were reported to sometimes contradict the physical cues that participants were witnessing, such as seeing smoke in the distance. One participant stated that they: could see the smoke and w[ere] looking at the Hazard app, and it wasn't listed in there. (NSW/ACT, 20).

This also lowered trust.

Many participants wanted the maps to display more information, including additional topographic details, more detail on whether the bushfire was under control or not, and where safe areas were located, amongst other things. In contrast, other participants felt that the maps they accessed had too much detail, which made it challenging to focus on what information was relevant to them.

Finally, some participants noted challenges related to the accessibility of maps, ranging from poor internet service and incompatible devices to a lack of comprehension.

There's a lot of people … that, yeah, they can send an email and that, but working maps and PDF files and things like that can get complex. (NSW/ACT, 16)

When asked how to improve maps, participants across the three locations identified several improvements. Those who had accessed less-detailed maps in the past wanted more information on bushfire spread predictions, including the current locations of a bushfire and where it might spread over time. Participants from all three locations wanted maps to show additional information such as road closures, wind speed and direction, bushfire front location and predictions, the confidence levels of the predictions, the burnt areas and their spatial accuracy, and the time of the last update and/or expiry time for the map. There was a desire for more clarity on how often maps were updated and on particular features of the map, such as the burnt area, i.e. whether or not the entire area had burnt through or not.

Discussion

The majority of participants in this study (92%) used maps during their recent bushfire experience. For some participants, maps allowed them to better comprehend the risks they faced, whereas others found they lacked timely information. Most participants were able to access maps easily, using a range of platforms including state emergency agency mobile applications, weather mobile applications, and Facebook. There was also a high level of general map use within our sample, with 77% using maps at least once a week. In general, maps were one tool in a toolbox of information sources that participants used when making decisions regarding bushfire response.

The tendency of participants to access multiple information sources, including multiple maps, and their desire to have timely updates aligns with Cao *et al.* (2017) and their idea of 'self-reliers' who make personal risk assessments based on multiple sources of information. 'Map hacking' and cross-referencing were methods identified in the present study that participants used to improve their understanding of their risk level. Similar information-seeking in this manner has been identified in other hazards such as hurricanes (Morss and Hayden 2010) and during wildfire smoke pollution events (Santana *et al.* 2021). Although maps alone are unlikely to satisfy information-seekers' desire for knowledge, they are an important visual tool that helps anchor the meaning of texts and make information easier to interpret and remember (Mortensen *et al.* 2017). Both the present study and the study of Cao *et al.* (2017) focus on bushfires in Australia. Owing to the Australian public making their own decisions about whether to evacuate or to stay and defend, they may be more inclined to be 'self-reliers' as they want multiple sources of information to help them make an informed evacuation decision.

The level of trust participants placed in maps was impacted by inconsistent information due to some mobile applications updating more frequently than others combined with limited information on when maps were published and when they would next be updated. This reduced the credibility and therefore perceived usefulness of the information being displayed. A study by Dootson *et al.* (2022*a*) found that conflicting cues between information sources can prevent individuals from taking protective actions during bushfire events. Additionally, recent studies on the impact of timely information in hazard events are lacking (Steelman *et al.* 2015); however, a study by Cohen *et al.* (2007) also links the timeliness and clarity of bushfire information to its usefulness in decision making.

Recommendations from the participants for map improvements were focused on increasing the amount of information provided by the map. There are arguments for including detailed hazard information, such as predicted impact zones, on maps of at-risk communities. They can increase understanding of the hazard within a population, allowing individuals to make their own judgements and decisions on risk and protective behaviour, rather than relying solely on official warnings (Rollason *et al.* 2018). However, concerns regarding the ability of some individuals

to access online maps and the high level of comprehension required to interpret some of the maps was raised by a participant. Studies on digital literacy in Australia show lower levels of digital skills and poor internet access in rural areas (Marshall *et al.* 2024). Individuals who are less digitally literate may have not felt welcomed to participate in the study as they are less likely to have accessed and used maps, which are now published primarily online. In addition, concerns surrounding the ability of some of the general public to interpret and make decisions based on predictive, or uncertain, hazard maps have been identified in several studies (Cheong *et al.* 2016; Lindell 2020; MacPherson-Krutsky *et al.* 2020). Miscomprehension of what the map displays can result in harmful and incorrect decision making.

Practical implications

For bushfire maps to be a more useful tool in decision-making, it should be a fundamental design principle to have the map clearly time-stamped so that inconsistencies between information sources can be better understood and managed by the public. It is standard practice for the bushfire maps produced by official state authorities in Australia to either have time-stamps on them or for the hazard icons and messages on the map to be time-stamped; however, it may be that these time-stamps need to be more obviously displayed to users. Ensuring consistent and timely updates to bushfire maps will also increase their credibility and use in decision-making. Time-stamping of maps is commonplace in other hazards; for example, the US National Hurricane Center produces predictive hazard maps for hurricane warnings (National Hurricane Center 2024). These maps are time-stamped with their time of creation and also include a predictive pathway for the hurricane that is time-stamped with the time when it is expected to impact specific locations. This approach may help individuals understand their risk better and manage inconsistencies between sources of information; however, studies on public comprehension of the predictive hurricane maps have highlighted issues with interpretation of the predictive impact zone (Ruginski *et al.* 2016; Evans *et al.* 2022), indicating that time-stamping alone is not enough to ensure map comprehension.

Authorities and state emergency services should also consider increasing the level of information that is provided on their bushfire maps. However, there is a balance to be achieved between providing simple, easy-to-understand maps while also providing additional information for those who desire it. This may be accomplished through adding optional layers to maps where users can select what information is shown to them. Other natural hazards maps have utilised layers to equip the public with more knowledge. A study on volcanic hazard maps (Ogburn *et al.* 2023) found that these additional layers show additional information such as town locations, infrastructure information and population density. In addition to providing more information on maps, efforts focused on upskilling and training individuals in rural communities prior to bushfire seasons so that they are able to access and use maps may be of benefit for those who are less experienced with the internet and maps. For these individuals, it is also important that community meetings and physical maps are provided. The amount of information portrayed in maps, and how this should be displayed, is an important area for future research that explores whether such changes to maps will actually improve understanding of risk and uncertainty. Future work packages in this NHRA study seek to develop bushfire prediction maps that effectively support decision-making. How to achieve effective community training and upskilling is another important area for future research.

Study limitations

One of the key limitations of this study is the low diversity of the sample. Our sample was skewed towards older respondents, even after attempts to recruit younger participants via targeted social media ads. A contributing factor is likely the fact that two of our study locations (i.e. Huon Valley Council and Snowy Monaro Regional Council) have slighter higher median age values, according to the Australian Bureau of Statistics (2021). Younger people tend to be more familiar with technology and may therefore have a different experience in locating and interacting with maps. Also, individuals who are less digitally literate or have limited access to computers may have been discouraged from participating in the study as they may not have had access to and/or used maps. As a result, our study sample may be skewed towards those who frequently use the internet or maps for information.

Another limitation of this study is that the study focused on three communities within Australia. These communities have a recent history of bushfires, meaning that participants may already have been familiar with how to access maps and the type of information they need to make decisions when faced with a fire. Future work packages within this research project will seek to engage individuals from other locations with varying experience with bushfires.

Conclusion

Bushfire maps are an important tool in conveying information on risk. They are used widely by the public in bushfire events, yet our knowledge of how they are used and how they can best be designed is limited. This study identified the key challenges associated with bushfire map use in Australia. The results of this study highlighted that bushfire maps need to be clearly time-stamped and need to display an appropriate level of information, perhaps through the use of layers to provide for the different information requirements across the public. In addition, training and upskilling

individuals to improve digital skills and map comprehension may increase access to maps in less digitally capable populations.

Supplementary material

Supplementary material is available online.

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