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Assessing the application and value of participatory mapping for community bushfire preparation

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ABSTRACT

The increased ease for individuals to create, share and map geographic information combined with the need for timely, relevant and diverse information has resulted in a new disaster management context. Volunteered geographic information (VGI), or geographic information voluntarily created by private citizens enabled through technologies like social media and web-based mapping, has changed the ways people create and use information for crisis events. Research has focussed on disaster response while largely ignoring prevention and preparedness. Preparing for disasters can reduce negative impacts on life and property, but despite strategies to educate communities, preparation remains low. This study assesses the application and value of VGI in bushfire risk reduction through a participatory mapping approach. It examines VGI as a social practice and not simply a data source by considering the user experience of contributing VGI and the potential for these activities to increase community connectedness for building disaster resilience. Participatory mapping workshops were held in bushfire-risk communities in Tasmania. Workshop activities included a paper-mapping exercise and web-based digital mapping. Survey results from 31 participants at three workshops indicated the process of mapping and contributing local information for bushfire preparation with other community members can contribute to increased social connectedness, understanding of local bushfire risk, and engagement in risk reduction. Local knowledge exchange was seen as valuable, but the social dimension appeared even more engaging than the specific information shared. Participants reported collaborative maps as effective for collating and sharing community bushfire information with a preference for digital mapping. Some limitations of online sharing of information were also reported by participants, however, including potential issues of privacy, data quality and source trustworthiness. Further work is needed to extrapolate findings from the study sample to the broader population.

1. Introduction and background

1.1. Bushfire preparation and community engagement

Community preparation is a fundamental component of bushfire safety. Preparation can assist residents to protect houses and property, and to evacuate safely. Recent studies have investigated factors influencing preparation decision-making (Prior, 2010), the importance of 'mental preparedness' (Eriksen & Prior, 2013), measures of adequate preparedness (Dunlop, McNeill, Boylan, Morrison, & Skinner, 2014; Penman et al. 2013), preparation costs (Penman, Eriksen, Horsey, & Bradstock, 2016), gender (Whittaker, Eriksen, & Haynes, 2016), and levels of preparedness in specific bushfires (McLennan, Elliott, Omodei, & Whittaker, 2013; Whittaker, Haynes, Handmer, & McLennan, 2013). Despite community education strategies and the impact of past events, active disaster preparation remains low (Gargano, Caramanica, Sisco, Brackbill, & Stellman, 2015; Hausman, Hanlon, & Seals, 2007; Paton, 2003). There is increasing recognition in emergency management that information provision alone is insufficient to increase community preparation and that more engaging, participatory approaches are needed. This reflects a shift in disaster management more broadly, where community participation is increasingly considered a fundamental principle of disaster risk reduction (DRR)

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and resilience building (e.g. UNISDR, 2015). In Australia, the principles of shared responsibility and community participation are embodied in the National Strategy for Disaster Resilience (COAG, 2011).

In Australia, community participation in fire and emergency management is a well-established practice. The Victorian Country Fire Authority's 'Community Fireguard' program, for instance, was established in 1993 to engage and educate groups of interested neighbours about bushfire preparation (CFA, 2016). The community development approach adopted by the Tasmania Fire Service (TFS) involves a 'Bushfire-Ready Neighbourhoods' (BRN) program, in which communities are selected based on bushfire risk, capacity and community interest, and bushfire education events and activities are tailored to their local needs. The program aims to provide information to enable people to develop their own bushfire survival plan and be better prepared for the bushfire season (TFS, 2014). Similar programs exist in Canada ('FireSmart-ForestWise') and the USA ('Firewise Communities'), with assessments suggesting that neighbourhood programs help to reduce bushfire (or wildfire) risk but also enhance social connectedness and resilience (MacDougall, Gibbs, & Clark, 2014; McGee, 2011).

Community engagement and participation in disaster management is typically initiated and managed by official agencies. Increasingly, however, community capacities for initiating and managing activities throughout the prevention, preparedness, response, and recovery (PPRR) phases are recognised (e.g. Scanlon, Helsloot, & Groenendaal, 2014; Whittaker, McLennan, & Handmer, 2015). Recent examples include the 'Student Volunteer Army' that formed in the aftermath of the 2010–11 earthquakes in Christchurch, New Zealand, to help residents clean up liquefaction (Villemure et al. 2012), and the group of local volunteers that travelled to Dalchowki village, 3 h from Kathmandu, following the 2015 Nepal Earthquake to distribute donated tarpaulins, food and anti-diarrheal tablets (Rousselot, 2015). Key advantages of such activities are that local volunteers often arrive on the scene before official agencies, have considerable local knowledge, and are highly responsive and adaptive to changing local needs. The greater accessibility and sophistication of information and communication technologies has seen considerable growth in digital volunteerism in disaster management, with the emergence of volunteered geographic information (VGI), in particular, changing the ways impacted citizens, the broader public, and emergency management agencies participate in disaster management (see Haworth & Bruce, 2015).

1.2. The emergence and promise of VGI

VGI refers to user-generated content with a spatial component, which involves the voluntary collection, organisation and dissemination of geographic information (Elwood, Goodchild, & Sui, 2012; Goodchild, 2007; Tulloch, 2008). Technologies such as the Internet, GeoWeb 2.0, global positioning systems, cloud storage, broadband communication, social media and personal locational devices, including smartphones, have enhanced the visibility of practices involving the creation and sharing of geographic information by private citizens (Goodchild, 2007; Palen & Liu, 2007). The wide usage of smartphones with multimedia capabilities and increased collaborative potential through the proliferation of social media provides innovative opportunities for individuals to contribute towards and consume a collective knowledge base, allowing users to engage with geographic information systems (GIS) in an unprecedented social way (Jayathilake, Perera, Bandara, Wanniarachchi, & Herath, 2011).

Researchers have reported on the promise of VGI to address issues and provide opportunities for a range of fields and applications. For example, as a resource for spatial data infrastructures, Genovese and Roche (2010) report on the opportunities for VGI to empower citizens in developing countries by making them part of collaborative local governance and enhancing the information used by decision makers. Community participation in local decision making has been recognised as fundamentally important for regional democracy, and thus the potential contribution of VGI is significant (Genovese & Roche, 2010). Elwood et al. (2012) describe opportunities for GIS and geography scholars provided by the dense network of individual, intelligent observers associated with VGI. Biggs et al. (2014) point to the opportunity of VGI to harness traditional ecological knowledge (TEK) under increasing climate and environmental pressures. TEK constitutes the cumulative and dynamic knowledge, practices and beliefs of local cultures about living things and the environment, and the importance of its inclusion in analyses of community livelihood security is gaining increased global recognition (Biggs et al. 2014).

Alongside the promise of VGI, there are important broader implications. Changes to traditional authoritative systems catalysed by VGI involve decentralisation of power and increased empowerment of citizens, where value is increasingly recognised in both expert- and citizen-produced information, initiatives and practices (Haworth, 2016).

1.3. VGI in disaster management

The increased ease of individuals to create, share and map geographic information combined with the need for timely, relevant and diverse information during disaster events has resulted in a new disaster management context (Goodchild & Glennon, 2010; Haworth & Bruce, 2015). Social media and web-based mapping platforms have changed the way people create and use information for crisis events (Liu & Palen, 2010; Ostermann & Spinsanti, 2011). This includes basic use of sites like Facebook to share text, images and videos (Bird, Ling, & Haynes, 2012; Taylor, Wells, Howell, & Raphael, 2012) as well as more complex activities such as data mining or crowdmapping (Meier, 2012). Bittner, Michel, and Turk (2016) describe a continuum of participation in volunteer mapping for crises, ranging from passive viewing to map establishment, and argue crisis maps promise bottom-up participation and a departure from hierarchical crisis communication and response. Through rapid exchange of geographic information between authorities and citizens for disaster response, and promoting community connectedness and engagement in disaster preparation practices, VGI contributes to all PPRR phases of disaster management (Haworth & Bruce, 2015).

VGI presents both opportunities and challenges for disaster management (Haworth & Bruce, 2015; Haworth, 2016). VGI cost-effectively increases the speed and reach of communications between authorities, affected-communities and the broader public, and facilitates collection of large volumes of diverse information from people in and outside disaster-affected areas. While local knowledge is critical for understanding risk, vulnerability and specific emergency strategies, VGI enables people outside the disaster location to assist in managing disasters, as demonstrated by volunteer involvement around the world in mapping impacted areas following the 2010 Haiti earthquake (Meier, 2012). By giving citizens more control over information mobility, technologies such as social media, smartphones and the web empower people to be more involved in disaster management, more connected to each other, and potentially better-prepared to respond to an event. These technologies are becoming increasingly familiar to large portions of the global population. People in emerging and developing countries are more likely to engage in social media than developed countries, even though internet use is lower (Poushter, 2016). For

smartphones, however, research indicates users are more likely to consume locational information and services rather than contributing their own VGI (Ricker, Schuurman, & Kessler, 2015).

A priority challenge of VGI is data quality (see Senaratne, Mobasheri, Ali, Capineri, & Haklay, 2016). As VGI is data from the crowd and lacks the same standards and checks as authoritatively-produced data, some have questioned its quality and therefore usability in high risk scenarios such as emergencies. Reported issues include erroneous or spurious postings, lack of contributor credibility, and misleading information (e.g. Bird et al. 2012; Gupta & Kumaraguru, 2012; Hung, Kalantari, & Rajabifard, 2016). Issues of privacy, malicious data use, and personal and information security have also been described (e.g. Shanley, Burns, Bastian, & Robson, 2013). Related are concerns over liability, particularly as VGI spans the globe via the internet and legal parameters vary across jurisdictions (Scassa, 2013; Shanley et al. 2013). Uncertainty also exists regarding who will contribute VGI, and when, what, or how they will volunteer. This is not to say VGI is unreliable, but that it should be treated as a supplementary data source alongside others rather than in isolation (Whittaker et al. 2015).

Increased volumes of data produced through platforms like social media means data management is another key challenge, with many disaster agencies lacking dedicated resources to manage VGI, limiting uptake and innovation (Anikeeva, Steenkamp, & Arbon, 2015; Latonero & Shklovski, 2011). Further, the unstructured nature of VGI conflicts with emergency management's top-down approach to information dissemination (Haworth, 2016; Palen & Liu, 2007). Finally, some argue VGI contributes to the digital divide (Norris, 2001), with those without access, time, money or capability to utilise these 'empowering' technologies becoming further marginalized (Crawford & Finn, 2015; Sui, Goodchild, & Elwood, 2013).

Literature in this field has tended to focus on disaster response while largely ignoring prevention and preparedness (Haworth & Bruce, 2015). This study differs in that it focusses on assessing the application and value of VGI in preparation for a potential bushfire. VGI studies have also tended to be data- or technology-driven, with a paucity of work on VGI theory or applications (Granell & Ostermann, 2016). Through examination of VGI as a social practice, or as a human activity involving collaborative behaviour, and not simply a data type, this research provides an alternative/novel methodology for evaluating its role in disaster management. It considers not only VGI data, but also the user experience of contributing VGI and the potential for participatory mapping to increase community connectedness. VGI conceived as a social practice also involves considering how processes, relationships, and products of VGI represent knowledge, and the social and political relations that shape, and are shaped by, VGI, including who is included or excluded from VGI practices and why (Elwood et al. 2012).

1.4. Participatory mapping

Involving local communities is a prerequisite to sustainable DRR (Gaillard & Maceda, 2009). Gaillard and Maceda (2009) note that community-based DRR fosters participation by involving communities in the identification of risk (including hazards, vulnerabilities, and capacities) and ways to reduce it. Although official information is critical, such participation can provide more up-to-date and locally relevant risk information (Jing, Liu, & Gang, 2013).

One approach to involving communities in DRR is through participatory GIS (PGIS), or public participation GIS (PPGIS). PGIS and PPGIS are both established fields, but with continuing ambiguity over their application in practice (Brown & Fagerholm, 2015). Assigning greater privilege and legitimacy to local or indigenous spatial knowledge, PGIS emerged in response to critiques of the theoretical assumptions and social implications of GIS (Dunn, 2007). It involves providing skills and expertise for community members to create maps themselves to represent their individual spatial knowledge (Corbett, 2003), with the intent to facilitate participatory decision-making processes, community advocacy, and increased empowerment for communities involved (McCall, Martinez, & Verplanke, 2015; Tulloch, 2007). The assumptions underpinning PPGIS are that local people know their landscape, the interacting socio-economic and environmental processes, the nuances of social behaviour, local culture and institutional structures, and can identify mechanisms for resilience and coping (McCall et al. 2015). It is not our intention in this paper to unpack the differences between the two approaches (for analysis on this topic see Brown & Kyttä, 2014), but rather we adopt Brown and Fagerholm's (2015) clarification of 'participatory mapping' to describe any process where citizens are involved in creating maps, which includes VGI.

Although there is overlap and connectivity between PPGIS and VGI (Tulloch, 2008), the placement of VGI within the critical GIS studies is contested (McCall et al. 2015; Sieber & Haklay, 2015). VGI is considered less participatory and critical with an emphasis on the volume of data collection rather than depth of information, and provides opportunity for social empowerment at a macro scale but is limited at an individual level (McCall et al. 2015). Based on Borgmann's 'device paradigm', Sieber and Haklay (2015) consider PPGIS as focused on *cultural information* while the mechanisms of VGI further promote the provision of *technological information*. There is a need for continued exploration of the relationship between PPGIS and VGI, areas of overlap and points of divergence (Cinnamon & Schuurman, 2013; Tulloch, 2008). The current study draws on PPGIS theory and collaborative practices in harnessing local spatial knowledge and encouraging information sharing through the use of VGI based techniques that extend beyond the 'device paradigm' as termed by Sieber and Haklay (2015) associated with the proliferation of location-aware technologies.

Participatory approaches can be considered to offer communities an efficient, cost-effective method for making robust observations (Acker, Lukac, & Estrin, 2010), with technologies, such as the GeoWeb, multimedia, and mobile GIS addressing issues related to the traditionally uneven access to digital spatial data, GIS, and the societal processes that incorporate them (Elwood, 2006). However, Cavallo, Lynch, and Scull (2014) argue for critical evaluation of the beneficial impacts of such technologies on citizens' interaction with government institutions and potential for narrowing the digital divide as their findings suggest that differential participation in VGI initiatives will reflect demographic profile.

GIS and mapping have long been important for DRR and fire management, with applications such as remote sensing for forest fire hazard assessment (Chuvieco & Congalton, 1989), and computer modelling methods for understanding fire behaviour and risk (Keane, Drury, Karau, Hessburg, & Reynolds, 2010). Participatory mapping, however, enables communities to delineate areas they perceive as vulnerable and prone to hazards, and to plot desired and useful risk reduction measures (Gaillard & Maceda, 2009). Jing et al. (2013) describe a community-based system which allows local residents to report risk information for disaster mitigation, which is both accessible to the community and useful for decision-makers. In the specific case of fire, public participation science research may lead to more effective wildfire management by increasing knowledge and prominence of wildfire issues in communities and providing opportunities for professionals to work with community members (Ferster & Coops, 2014). Ferster and Coops (2014) evaluated the quality of data collected via participatory mapping by tasking a group of volunteers to record forest fuel loading using smartphones. They demonstrate the value of these techniques but

also recognize the need for further investigation on the importance of understanding the range of participant experience and motivations. Importantly, Corbett (2003) argues the participatory mapping process can contribute to building community cohesion, help stimulate community members to engage in land-related decision-making, raise awareness about pressing issues, and contribute to empowering local communities.

Critique of PPGIS has traditionally focused on claims that participatory GIS disempowers or marginalizes communities through the complexity of the technology, the high associated costs, the inaccessibility of data, and a lack of genuine community participation (Corbett & Keller, 2005). VGI may address some of these concerns but still presents limitations including participant representational bias associated with disparity of access.

In this study we adopt a participatory mapping approach to considering VGI for bushfire risk reduction through community workshops. It has been shown that participatory mapping through other methods, such as household surveys, produces more accurate and complete spatial data, with workshop methods recognised as being appropriate for planning processes rather than as producing quality data for decision support (Brown et al. 2014). Workshops tend to allow for more qualitative data (Brown et al. 2014; Mayoux, 2006), including through participant discussions and researcher observations. Workshops facilitate interaction and collaboration between participants, with greater emphasis on the participation with others and the mapping process over data production, and therefore are the most suitable method for this study. These participatory approaches not only contribute to knowledge gained by the researchers, but also from the development of participants' knowledge and understandings gained (DeLyser & Sui, 2014). The qualitative sampling approach adopted in this study was conceptually driven to support the research questions and allow analytical generalisations rather than robust statistical generalisations applied across broader populations (Curtis, Gesler, Smith, & Washburn, 2000). However, it is important to consider the effects of sampling when adopting workshop-based methods. Those who participate in workshops as volunteers may be more likely to introduce biases into the mapping process than participants recruited through random sampling (Brown et al. 2014), which is a significant consideration for evaluating VGI practice broadly.

1.5. Study aims

The aim of this study is to assess whether the process of mapping, contributing, and sharing local information for bushfire preparation with other community members can increase an individual's social connectedness, awareness and understanding of local bushfire risk, and their engagement in risk reduction. More specifically, we asked the following questions:

1) Does the social practice of contributing and reviewing VGI increase engagement in bushfire preparation?
2) Does the activity of collaborative mapping increase community connectedness?
3) Is the local knowledge and understanding gained from the mapping process of value to communities?
4) Is the map itself perceived as an effective medium for collating and sharing community bushfire information?

2. Methods

2.1. Study sites and rationale

Participatory mapping workshops were held in four bushfire risk communities in Tasmania, Australia (Fig. 1). Much of Tasmania is covered by bushland and potential fire hazard. Bushfires are the most economically disastrous of all natural hazards in the state and the impacts on communities are long-lasting (Frandsen, 2012). The Black Tuesday bushfires in 1967 around Tasmania's capital, Hobart, caused 62 deaths and destroyed over 3000 buildings (EMA, 2011). Disastrous bushfires impacted the south east of Tasmania in January 2013, destroying 203 residential buildings with an overall financial cost in the order of $100 m (and this estimate does not include the additional costs of emergency response and recovery operations or consequential costs to public and private sectors) (DPAC, 2013). The 2015-16 Tasmania bushfire season exhibited above-normal risk conditions as a result of recent warm years and low rainfall (BNHCRC, 2015). Authorities recognize that a projected 250% increase in the area of Tasmania categorised as 'Very High Fire Danger' during spring by 2081–2100 under a high emissions scenario will shorten preparation and recovery cycles (Fox-Hughes et al. 2015). Thus Tasmania is ideal for studies concerning bushfire safety.

Workshop locations (Fig. 1) were selected for their characteristics listed in Table 1. While aspects of sites were common, such as bushfire risk, diversity between sites was preferred to ensure identification of a breadth of VGI application issues across communities with differing geographies, existing levels of community engagement, community profile, and known fire history.

2.2. Participant recruitment

Participants were recruited through: (1) approaching participants involved in a previous related study (see Haworth, Bruce, & Middleton, 2015), (2) known local contacts, and (3) tailored invitations to residents, community fire groups, local businesses, community organisations and other local services including schools. As Tolmans Hill is an entirely residential area, workshop information was mailed to all households ($n = 240$) six weeks prior to the event, and flyers placed in a random sample ($n = 50$) of letter boxes one week prior to the event. Information was also mailed to a random sample of households in St Marys ($n = 150$) and St Helens ($n = 150$) as local contacts were limited. Workshops were advertised more broadly in local council newsletters and online through social media and other relevant websites (e.g. Tasmania Fire Service, community organisations), and through targeted promotion on Facebook (based on geography and age > 18).

2.3. Workshop process

Workshops were held in local venues over three weekends in November and December 2015 over a 4–5 h period. Workshops allowed participants to test multiple mapping methods with hands-on activities tailored to their community, and enabled the experience of undertaking these tasks together with other community members to be evaluated. Each workshop included a short introductory presentation, a paper mapping activity (approximately 90 min), a lunch break (30 min), and a digital mapping activity (approximately 75 min) before participants completed a questionnaire (15 min). Present at each workshop was the lead author, an assisting researcher, and a TFS representative from the BRN program. While the fire service were represented at each workshop, it was made clear to participants in advance that the purpose of the workshop was to contribute to the research and that information they contributed would not be utilised by the Tasmania Fire Service or directly inform official emergency management practices in their area.

The lead author introduced the facilitators, provided background on the research and study aims, and explained the workshop activities. The first activity involved paper mapping whereby

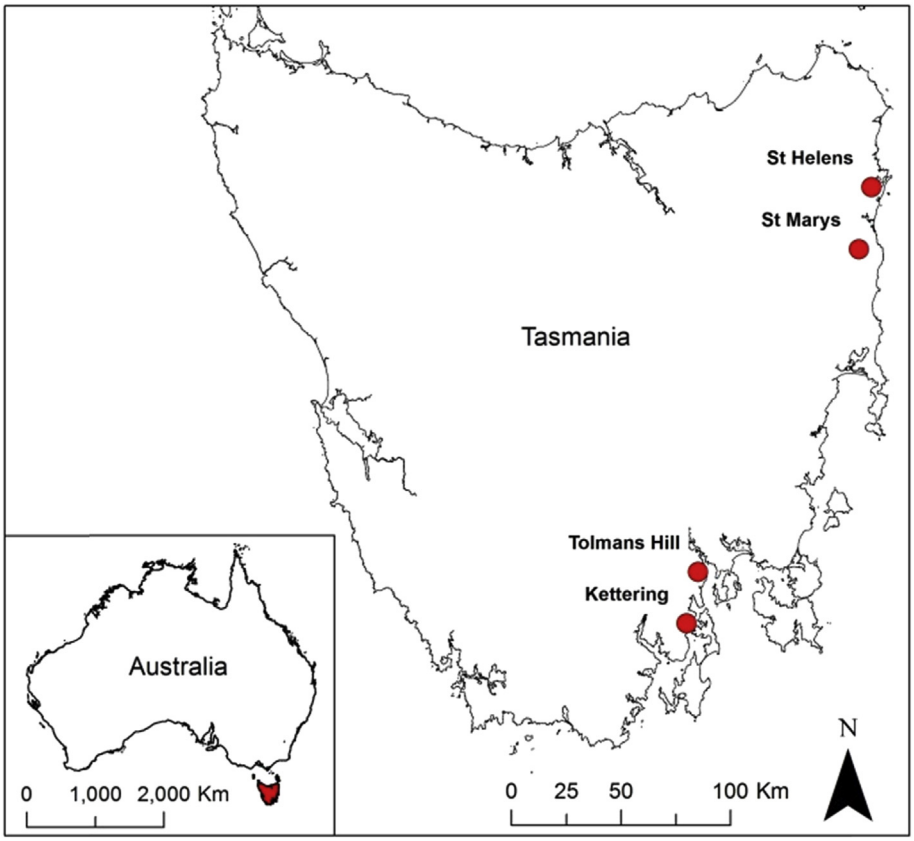

Fig. 1. Workshop locations within the state of Tasmania.

participants in groups of 2–5 were given a hardcopy satellite image (size A1), topographic map (size A1), community protection plan (an official TFS document outlining 'nearby safer places' and other relevant information) (size A2), blank paper, plastic overlays, and a suite of coloured markers, stickers and other stationary. Participants were asked to add information to the maps they considered relevant to bushfire preparation in their community, using any combination of the provided-resources. With the focus of the exercise on the experience of collaborative mapping, the content participants should map was not prescribed. However, facilitators provided guidance through discussions during the activity on what might be appropriate to include, such as local knowledge on areas perceived as vulnerable to bushfire, community assets, resources available to people for preparing their homes, community groups, home-to-work travel routes, and potentially important sites in the event of disaster including alternatives to the TFS 'safer places'. At completion of the exercise participants presented their maps to the other groups for discussion. Fig. 2 presents an example of a paper map completed during the exercise.

The second activity (digital mapping) involved collating the information from each group into a combined web map. Though its GIS functionality is limited, the Zeemaps platform (www.zeemaps.com) was used for its simplicity and accessibility. Base maps were established for each community prior to the workshops to ensure consistency in geographic coverage with the paper maps (though participants could then zoom and pan), and a URL to the map enabled participants to contribute through a web browser on laptop computers, smartphones and tablets live in the workshop. Participants could view a street map and/or satellite image base layer. The platform allowed data to be added as points with

Table 1
Characteristics of workshop sites.

	Region	Bushfire risk[a]	Significant fire event[b]	Population[c]	Geography	Engaged bushfire groups[d]	Part of BRN program[e]
Kettering	South	Extreme	1967	984	Rural	Yes	Some works
St Marys	North East	Extreme	2006	800	Rural	Yes	Yes
St Helens	North East	Extreme	2014	1498	Peri-urban	No	Some works
Tolmans Hill	Hobart	Extreme	2014	490	Urban	No	No

[a] Tasmania Risk map, produced by Parks and Wildlife (PWS), 2010. Accessed 9/2/2016 at <https://wikis.utas.edu.au/display/ext03/Risk+Assessment+Mapping>.
[b] Significant: an event that at a minimum involved fire service attention. Emergency warnings may have been issued and/or community daily life was interrupted in some other way (e.g. road closure, closed businesses, injury or death). Various information/news sources.
[c] 2011 Census, Australian Bureau of Statistics (ABS).
[d] Did the community have pre-existing and visible operating community-led fire management-related groups? E.g. neighbourhood groups, annual meetings, established telephone trees.
[e] Bushfire-Ready Neighbourhoods: No, not part of BRN; some engagement works undertaken; Yes, current core community. <http://www.bushfirereadyneighbourhoods.tas.gov.au/>.

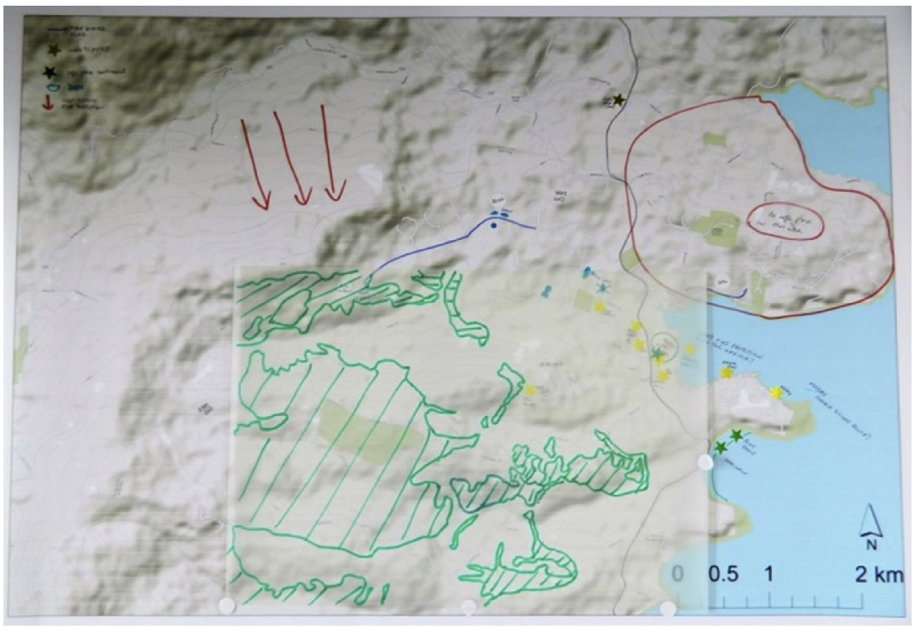

Fig. 2. An example paper map produced during the Kettering workshop.

different colours and icons and as regions in a choice of colours. A short description and photo could be added to an entry, and a description/attribute given to each entry automatically populated a legend. Participants were able to add and edit their own points, but administrative access was required to delete entries. Fig. 3 presents an example of a completed digital map.

A questionnaire was completed by participants to capture both quantitative and qualitative data regarding their views on key topics, including the user experience of mapping community information, mapping methods, local knowledge in community bushfire preparation, community connectedness, potential concerns such as privacy and data security, and future use of VGI. Questionnaire responses were collated and analysed in Microsoft Excel alongside Australian Bureau of Statistics (ABS) 2011 Census data. Key insights were gained through observation and informal discussions with participants during and following each activity that were later documented by the researchers.

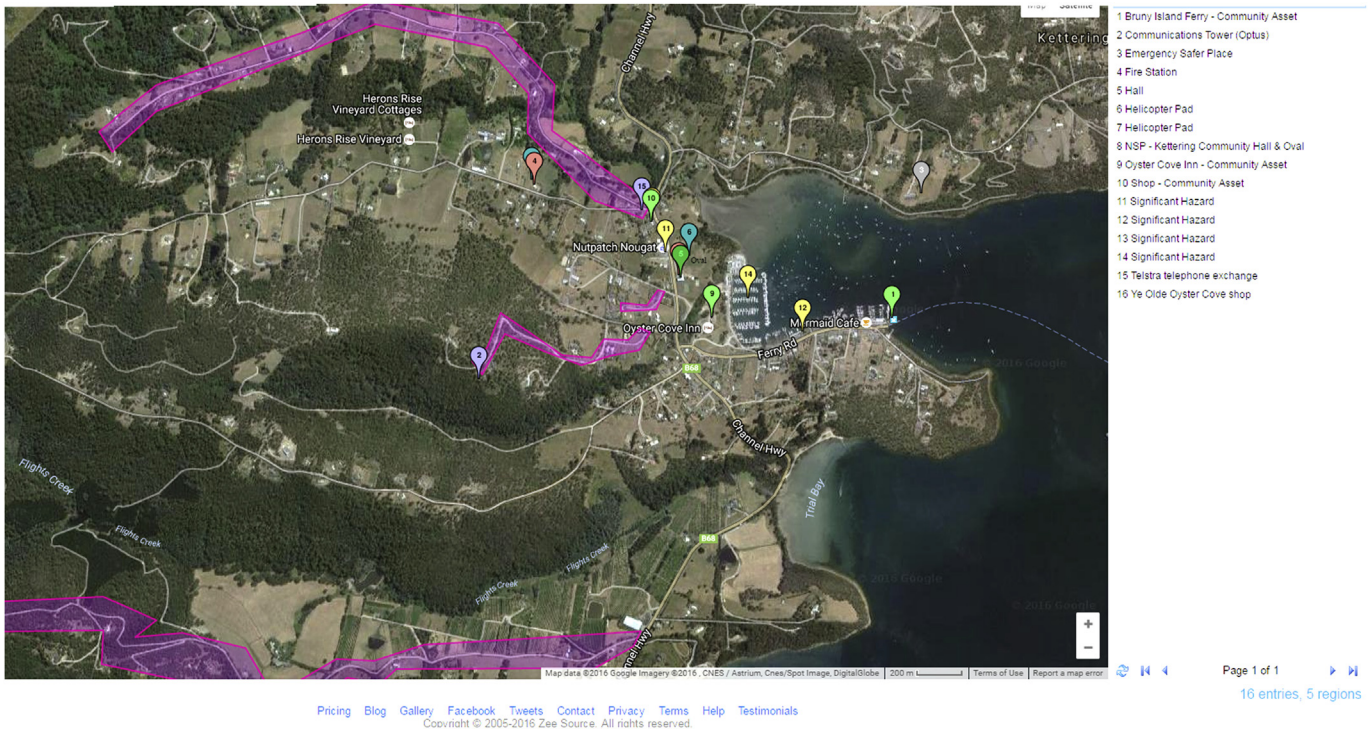

Fig. 3. An example digital map on the Zeemaps platform produced during the Kettering workshop.

3. Results

3.1. Participant demographics

Survey results from 31 participants are included in the following analyses (Kettering, n = 16; St Marys, n = 9; St Helens, n = 0; Tolmans Hill, n = 6). While more individuals attended workshops, not all returned a completed questionnaire. An even distribution of male (53%) and female (47%) participants attended. The age distribution of participants was skewed towards those over 35 (age 35–50 = 20%; 51–70 = 53%; >70 = 27%). Fig. 4 presents a comparison between age representation in the study samples for each workshop community and census population data. 90% lived in a household without children or dependents, either alone (10%), as a couple (67%) or with other adults (13%). Most participants had lived in their community for over 5 years (76%), with 24% living in the area for more than 20 years. 57% of participants had a tertiary qualification and the majority were either employed (47%) or retired (50%).

3.2. Workshop observations

3.2.1. Participant interactions

Participants appeared interested and motivated to learn and contribute to bushfire preparation in their community. They worked quickly and easily with others and discussions were lively. In particular, the paper mapping activity yielded a high level of participant interaction. Some participants described working with others, discussions between community members, and the increased community connections generated through the mapping activities as the most valuable aspects of the workshop (as opposed to the information gained or the maps produced).

Interaction appeared lower during the digital mapping activity. This may reflect the sequencing of activities and subsequent participant fatigue associated with the second activity. In some instances a particular group member controlled the input device (tablet, laptop computer, smartphone) leaving others in the group with minimal opportunity for interaction with some participants observed to be slightly intimidated by the technology. After initial hesitation, most, however, did engage with the activity and commented on the greater potential for mapping in their community enabled through internet and computer devices.

3.2.2. Group discussions

Dominant discussion points included what content to map, the differences between mapping methods, and how a VGI-derived map may be useful and applied in the broader community outside the workshop setting. Despite concerns about power outages during bushfire events and limited computer access, map ownership and administration, privacy, and the risk of malicious intent, overall discussions on the use of web mapping were positive.

Participants generally described a preference for digital mapping, in contrast to the observations described in Section 3.2.1. They discussed how online mapping would be useful for people who are less-engaged in more traditional bushfire preparation activities and

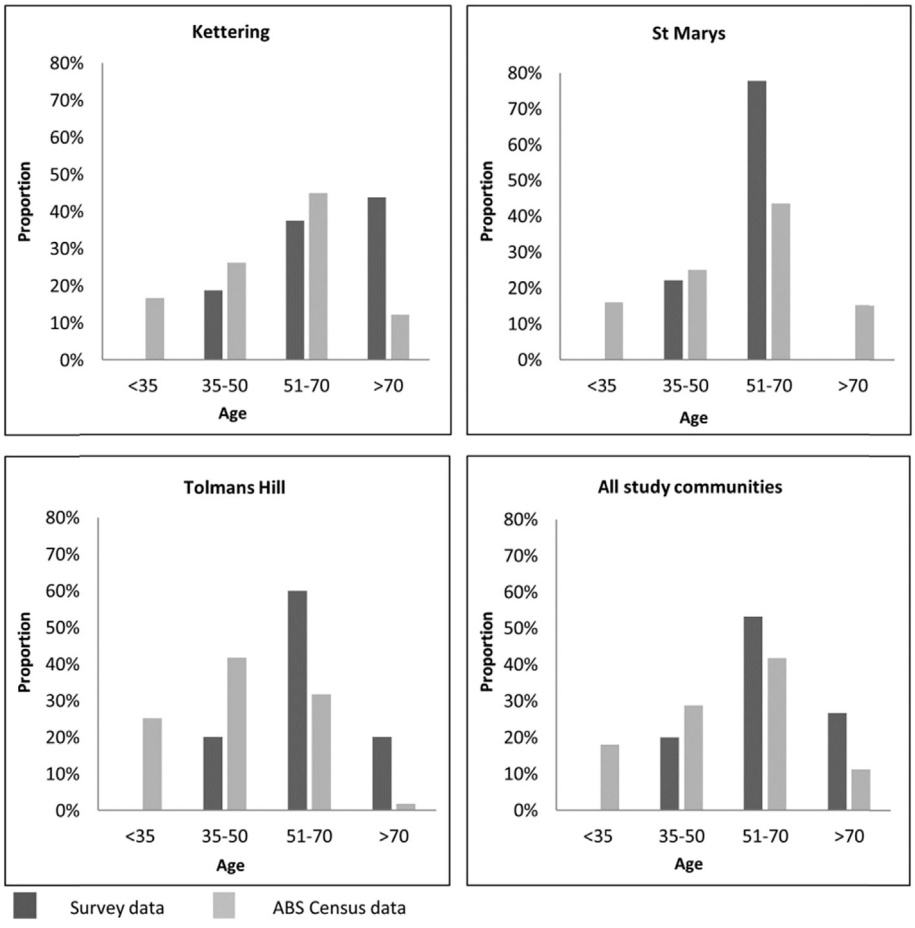

Fig. 4. Graphs for study communities presenting the proportion of workshop participants for each age group compared to ABS 2011 Census population data.

forums, including younger people, and vulnerable groups such as travellers, new residents, and those whose first language is not English. The web map was seen as preferable for examining finer detail information (e.g. ownership of particular tools in a neighbourhood), wider distribution, maintaining information relevance, the convenience of contributing when/where people desire, inclusion of more detailed comments and photos, and the potential for greater data use (e.g. GIS analyses).

3.2.3. The information contributed

The content participants chose to map focused on response to a potential fire event, and included services and community assets such as communications or food suppliers, potential hazards such as fuel stores or one-way roads, areas of increased risk such as dense bushland, 'safer' places to assemble and possible evacuation routes.

Significantly, the activities also revealed to participants how little they knew about other residents in their community, and how disconnected and unprepared their community possibly is. In Tolmans Hill, some described feeling uncomfortable knocking on their neighbour's door, which was in contrast to other communities visited, such as Kettering where participants appeared well-connected and were including neighbourhood-level bushfire management groups on their maps. Participants discussed how important sense of community might be for improving bushfire preparedness in Tolmans Hill. Referring back to the community map, they identified locations for a playground and a coffee shop that may be useful in building community connections. Participants regarded the content they mapped as more useful, and most needed, for strengthening engagement in bushfire preparation within their community than for use by emergency response services.

3.3. Questionnaire responses

3.3.1. The user experience of mapping community information

Broadly, participants described the experience of mapping their own information for their local community positively. 97% of respondents stated the activities were useful for their bushfire preparation, 97% thought maps in general were an effective way to present and share their information, and 77% learnt something new about bushfire preparation in their community through the mapping exercise. Participants stated discussions informed them of the preparation approaches taken by others, and having access to a broader range of community knowledge helped highlight how the community may struggle to manage a large bushfire.

Undertaking the activities with other community members was seen as important, with all participants reporting working with others as a positive experience, and 94% confirming that it helped them understand the broader bushfire risk and preparation activities in their wider community. Some participants commented on the local knowledge of individuals, and how bushfire preparation should be a collective effort. For example:

> "If two brains are better than one, then 17 brains have to be even better! Each person has personal knowledge of their own environment and neighbours not necessarily known by others in the overall community" (questionnaire response, workshops 2015).

Others commented they were not aware of each other's resources, capabilities and fire safety concerns prior to the mapping activities.

Fig. 5 presents participants' perceptions of various aspects of the participatory mapping activities, depicting strong modal scores of 4 (agree) for all items and overall positive feelings for the experience of community mapping for bushfire preparation.

While a low percentage had concerns (26%), some points raised by participants to consider in sharing information to a public community map included the accuracy of information and how it can be verified, privacy and awareness of who can access and use the information, and security concerns. Despite this, 86% of participants stated they would contribute to community maps similar to those used in the workshop in the future.

3.3.2. Paper mapping versus digital mapping

In response to questions on the differences between paper mapping for sharing community VGI and digital mapping, participants described strengths and weaknesses of each method (Table 2). Fig. 6 shows participant preferences for either paper mapping or digital mapping, and which method they perceived as more useful for their broader community.

3.3.3. The information mapped

Participants described favourably the mapped information itself. 84% felt the information was personally relevant and 74% felt it increased their understanding of community bushfire preparation. 93% felt VGI would be useful to emergency management authorities. 94% believed participatory VGI increased their awareness of other community members and their preparedness, and all participants reported the information would be useful to other members of their community. One participant commented:

> "People living in our area don't know what others have available. I.e. water, safer place. Not everyone is aware of particular hazards" (questionnaire response, workshops 2015).

4. Discussion

This study provides evidence for the application and value of participatory based VGI in community bushfire preparation. Results indicate that the process of mapping and sharing local spatial information for bushfire preparation with other community members can contribute to increased social connectedness, understanding of local bushfire risk, and individual engagement in risk reduction. However, the findings need to be considered in the context of the study sample.

4.1. Study sample

The limited and potentially skewed sample of 31 participants restricts extrapolation of the findings to the broader population, with particular underrepresentation of people <35 years of age and an overrepresentation of people >50 (Fig. 2). Vulnerable groups such as those experiencing greater levels of social disadvantage, supporting dependents, or visitors to the area are also underrepresented. In considering the broader application of VGI, if not 'everybody' in a community is contributing; can a map ever be fully representative? The lack of participants in St Helens, as well as the small sample size overall, reiterates the challenge of community engagement in DRR, despite innovative and sustained efforts through initiatives like BRN, which has also experienced variable participation rates (DSA, 2016). While the link cannot be assumed, if the lack of workshop engagement is related to a broader community disinterest in disaster preparedness this has relevance for community safety efforts. Though, others have reported that participatory mapping studies rarely result in representative samples and can exhibit biases towards older, more formally educated participants with higher incomes (Brown, 2016), and thus our

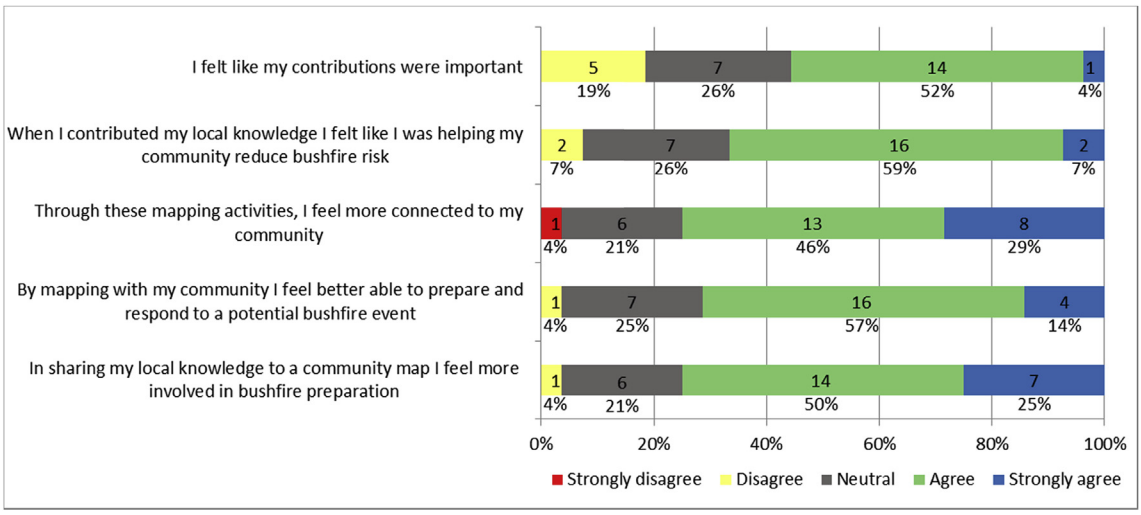

Fig. 5. Likert Scale item responses to participatory mapping exercises, showing a modal score of 4 (agree) for all items. The values on each of the bars represent the number of responses for each of either 'Strongly disagree', 'Disagree', 'Neutral', 'Agree', or 'Strongly agree' to the Likert Scale items, with the proportion of responses as a percentage underneath.

sample does not appear atypical.

Despite extensive recruitment efforts as part of the research design in the current study, recruitment was problematic, demonstrated by the lack of attendance at the St Helens workshop. An exhaustive approach, including broad-scale, community-wide promotion through digital and offline methods, as well as targeted invitations to key community individuals and organisations with tailored messaging, following the guidance of researchers at ExCiteS - UCL (personal communication 2015), still failed to result in a study sample representative of the broader community.

The limited study sample, however, does not devalorize results reported on the experiences of those that did participate. Participants spent a minimum of 4 h participating in the study, developing a deep engagement with the mapping activities, collaborating with other participants, and discussing their responses with the researchers, providing a rich dataset that includes a depth of understanding and appraisal of the participatory VGI methods proposed for bushfire preparation engagement. While the study collected quantitative data through the questionnaire, importantly it also facilitated generation of rich qualitative data through observations, focussed discussions, as well as sections of the questionnaire, thus further emphasizing the importance of 'small' contextual data and methodological pluralism (DeLyser & Sui, 2014). The study is more aligned with focus group methods, in which a typical useful sample size is 6–12 (Griffith, 2013), than broad scale survey methods which involve less participation and require much larger sample sizes. The benefits of such qualitative research is information drawn through experiences rather than the participant sample size (Sandelowski, 1995). If we accept the flaws in studies of this nature, such as limited sample population and response biases associated with surveys or workshops where participants self-select, we should consider the results of this study as indicative rather than definitive. We must recognize that the experience of those not represented in the study sample may differ from the results we report here.

4.2. Insights gained

In response to the first study aim, the experience of workshop participants suggests the social practice of contributing VGI was

Table 2
Strengths and weaknesses of VGI mapping methods identified by workshop participants.

	Strengths	Weaknesses
Paper mapping	Good for discussion/brainstorming	Difficult to maintain currency
	Inclusive activity	Unlikely to carry around final maps
	Good when technology is disrupted	Resulting maps easily lost or damaged
	More fluid input – e.g. sketching	Poor legibility
	Not reliant on power or internet access	Limited scale/boundary of the page
	Useful to issue to new residents or tourists	Limited audience/not easily communicated or shared
		Resource costs
		Information needs to be translated to digital to be used in other ways, e.g. in a GIS
Digital mapping	Higher resolution	Technology difficult for some to use
	Accessible to many	Digital divide – not everyone has access
	Collating various information	Technology failure
	Increased accuracy and greater detail	Inaccurate/false information
	Can zoom/pan to locations – changeable scale	Information verification – managing malicious intent
	Easier to edit and update	Cluttering of data on the map
	Storage	Ephemeral nature of GIS platforms
	Mobile accessibility	Dependent on power/internet access
	Multiple layers of information, e.g. satellite imagery	Time needed to learn the technology/software
	Data can be combined and manipulated with other databases	Who has access to the information mapped? E.g. the public, arsonists
	Other stakeholders can contribute information, e.g. fire service, police	
	Ability to share easily	

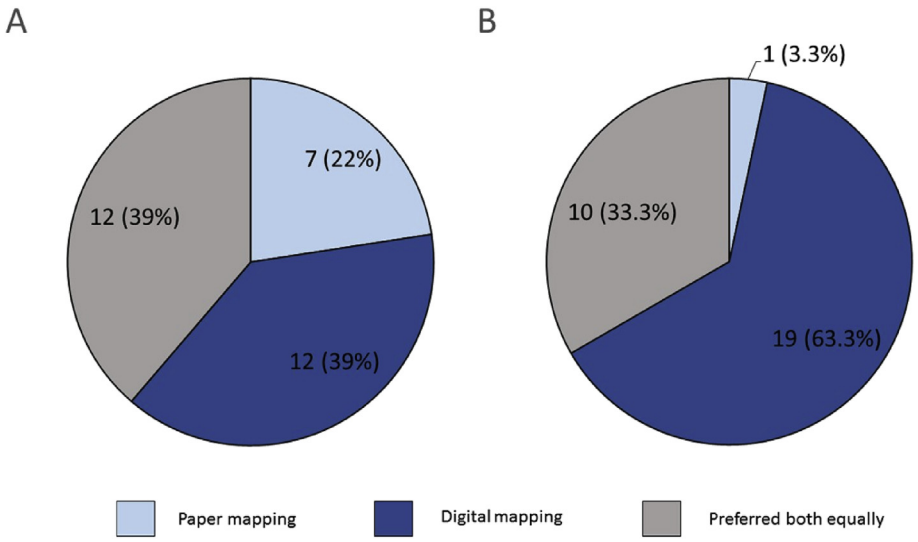

Fig. 6. The number and percentage of participants preferring each mapping method for A: themselves, and B: their broader community.

engaging for bushfire preparation. There was an understanding that everyone had different knowledge to contribute and that bushfires can affect all members of the community, thus managing risk should be a shared experience. The social aspect of VGI, with people connecting to each other through the mapping process, appeared even more engaging than the specific content being mapped. This should be a consideration for future DRR-engagement efforts. Others have reported that empowerment in PPGIS initiatives is linked to the participatory process, and the emphasis for a successful project should be on participation rather than technical components (e.g. Jordan, 2002).

Participants were observed to be most engaged in the workshops when they were able to map their neighbourhood fire groups and details about individual streets, with information at the local neighbourhood scale proving more personally relevant to participants. Mapping at broader geographic scales, such as the wider community level, produced relevant information, but was limited to content already available on existing maps, such as communication towers and dead-end roads, and failed to harness local expertise and lived experience in the same way achieved by finer-scale mapping. Gaillard and Maceda (2009) state while working at larger scales allows household-level detail to be mapped, it also requires more participants from a smaller area to gain enough data for use. McCall et al. (2015) argue that the focus in participatory mapping on smaller groups is its strength over most VGI projects that tend to be broad in coverage. Goodchild (2007) also pointed to the significance of scale, positing that the most value of VGI to geographers may be what it can inform about life's activities and the lived experience at local scales.

Regarding our second aim, the study suggests the act of group mapping can contribute to increased community connectedness. Greater analysis employing more complex psychological scaling measures is required to further this understanding. Taylor et al. (2012) show how social media helped people share information, connect and assist each other in response to a cyclone event in Australia in 2011, arguing that VGI activities promote connectedness and directly help reinforce social capital and community competence for disaster resilience. Social capital has been described as “the interconnectedness of individuals and organisations, in which strengths come through social support, sense of community and attachment to place” (Norris, Sherrieb, & Pfefferbaum, 2011; Taylor et al. 2012). Connectedness of individuals and sense of community were shown in this study to influence a community member's bushfire preparation, particularly in Tolmans Hill. Participatory mapping initially revealed how disconnected participants were, but then became a useful tool to aid in discussing strategies to improve sense of community. VGI and participatory mapping not only allowed communities to record their concerns, but also had transformative capacities in contributing to change and increased community connectedness. Through strong social networks, high levels of trust, and high civic participation, elevated social capital unites community members and is important for information dissemination and building shared attitudes and behaviours (Hausman et al. 2007), leading to improved disaster resilience (Murphy, 2007).

In the context of the third aim, local knowledge shared was of value to study participants with 94% reporting VGI increased their awareness of other community members and their preparedness contributing to the ongoing process of building community resilience. If disaster resilience and bushfire risk reduction is to be a shared experience and a shared responsibility, those involved must have a common understanding of each other's risks, responsibilities and actions.

In addressing the fourth study aim, mapping was perceived as an effective mechanism for collating and sharing community bushfire information, especially in digital form (Fig. 6). Given the study sample age bias towards older people, the preference for the technological solution over offline methods was unexpected. Research shows that Web 2.0 technologies are used more commonly by youth (Haworth et al. 2015; Perrin, 2015). However, given 57% of participants were tertiary-educated, the observed openness to digital mapping may in part reflect sample bias alluded to by Sieber and Haklay (2015) who warn of the potential for VGI to become the diversion of those who have the time, knowledge and education. Similarly, Bittner et al. (2016) question the promise of VGI to represent and empower ‘ordinary people’ and argue that those who can and do participate in crisis mapping often form a privileged minority. Our participatory mapping approach did reveal potential for such biases and participant characteristics, but, unlike involvement in other phases of disaster management, in the preparedness phase, well designed VGI initiatives at a focused community level could foster broader uptake. Corbett and Keller (2005) note as information technologies have proliferated and become easier to use, the role of the tools themselves in the empowerment

process has gained greater importance. For community bushfire preparation, a combination of paper and digital mapping may be appropriate in some instances to reduce the limitations outlined in Table 2 and facilitate participation of those who do not use VGI technologies.

Participants' concerns about potential inaccuracy of information and trust of non-authorized data sources have been reported elsewhere (Gupta & Kumaraguru, 2012; Haworth et al. 2015). Solutions offered include systems for determining a measure of credibility or data quality (Hung et al. 2016; Ostermann & Spinsanti, 2011), or reasoning for why data quality should not be a major concern, such as the evidence provided by Linus' Law and the Wikipedia model that demonstrates error reduction through collective agreement (e.g. Haklay, Basiouka, Antoniou, & Ather, 2010). However, we question whether numbers would reach a sufficient critical mass in community-scale mapping projects for effective self-correction. Other Web 2.0 platforms, such as eBay and Couchsurfing, have employed systems of contributor reputation ratings to increase information credibility and source trustworthiness (McCall et al. 2015). McCall et al. (2015) argue that trust is built over time in smaller participatory mapping groups, whereas validation is sought for broader scale VGI.

Privacy and consent issues were consistently raised, with participants concerned in particular about who would have access to information on a web-based platform. Information mapped about vulnerable people, for instance, may be sensitive, particularly if those formally classified as vulnerable do not view themselves in that way. Access of shared information to people with malicious intent (e.g. arsonists or thieves) also links the issue of information privacy to compromised personal security. Sieber and Haklay (2015) argue for the integration of societal value in system design and the need to anticipate potential geolocational privacy violations through embedded techniques for location masking. VGI also has potential to create or exacerbate conflict in communities. For example, the identification of unmanaged properties or unprepared households could generate tension or division, particularly if information is contributed without consent. The potential for VGI to create conflict within communities, possibly undermining community connectedness and social capital, warrants further research. Potential solutions for privacy and trust issues associated with VGI more broadly also require further research, particularly as addressing many of these matters will be dependent on policy and legislative arrangements which may vary across jurisdictions.

4.3. Future considerations

It is important to recognize that this study has measured increased community engagement based on survey responses and workshop observations related to people's *perceived* preparedness, rather than assessing change in actual bushfire preparation actions, such as existence of a survival plan, or long term behavioural change. This was beyond the scope of this paper and future analyses would strengthen this work by investigating longer-term impacts of participatory mapping as a bushfire preparation engagement mechanism.

This study does not comprehensively address questions concerning motivation, self-directedness and custodianship over VGI initiatives. Reliance on coordination, whether by community or authorities, may be required to ensure success of VGI applications (Sieber & Haklay, 2015). This becomes increasingly important if participatory maps are associated with funding or political agendas (Gaillard & Maceda, 2009). Further, without the impetus of research or an individual 'champion', would a VGI system be implemented and would it be maintained? The short lifespan of many web-based platforms, how seriously VGI maps are perceived by the viewing public, and the relationship between volunteers and emergency management authorities (Bittner et al. 2016) further challenges the sustainability of VGI practices. Governments are often restricted by top-down 'command and control' style frameworks which give little flexibility for supporting alternative initiatives (Gaillard & Maceda, 2009). Brown (2012) argues that government organisations' engagement with more inclusive participatory initiatives in regional and environmental planning has been limited due to a lack of specific incentives, the unpredictability that accompanies engaging the general public, lack of experience, the 'expert-lay-divide', and regulatory barriers. Longitudinal studies are required to determine opportunities for and barriers to sustaining participatory mapping initiatives maintained by communities and the appropriate level of organisational involvement and support.

5. Concluding remarks

Key contributions of participatory mapping in bushfire management include the promotion of social inclusion, capacity building, and enabling democratic participation. This study has demonstrated the role of participatory mapping, facilitated through VGI, in providing opportunities for community connectedness, local knowledge exchange, and individuals' engagement and responsibility in DRR. Further work is needed, however, to extrapolate findings from the study sample to the broader population. The low workshop attendance was a key finding in itself, reiterating the question of how a community can achieve social connectedness and disaster resilience if there are potential barriers to congregating for a common cause, emphasizing the importance of engagement with the broader population as an ongoing goal, particularly diverse and/or under-represented groups. Evidence of the benefits of involving community members in disaster management is mounting and emergency organisations should work to determine how they can support participatory bottom-up approaches and ensure present organisational systems are not a barrier to their success. Additional resources and funding may be required to manage issues such as large volumes of data and misinformation, but VGI-sharing in communities should be encouraged to increase risk awareness, the use of local knowledge and community engagement. In existing community engagement strategies, mapping can be utilised to raise local spatial awareness and for capturing, collating and distributing community bushfire information. However, VGI is not a standalone approach and successful community engagement will be achieved by employing a range of strategies.

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References

Acker, A., Lukac, M., & Estrin, D. (2010). *Participatory sensing for community data campaigns: A case study* (Technical report published by the Centre for Embedded Network Sensing).

Anikeeva, O., Steenkamp, M., & Arbon, P. (2015). The future of social media use during emergencies in Australia: Insights from the 2014 Australian and New Zealand disaster and emergency management conference social media

workshop. *The Australian Journal of Emergency Management, 30*(1), 22–26.
Biggs, E. M., Boruff, B., Bruce, E., Duncan, J. M. A., Haworth, B., Duce, S., et al. (2014). *Environmental livelihood security in south-east Asia and Oceania: A nexus-livelihoods approach for spatially assessing change. White paper*. Colombo, Sri Lanka: International Water Management Institute (IWMI). Retrieved 25 March 2016 from http://www.iwmi.cgiar.org/publications/other-publication-types/environmental-livelihood-security-south-east-asia-oceania/.
Bird, D., Ling, M., & Haynes, K. (2012). Flooding facebook – The use of social media during the queensland and Victorian floods. *The Australian Journal of Emergency Management, 27*(1), 27–33.
Bittner, C., Michel, B., & Turk, C. (2016). Turning the spotlight on the crowd: Examining the participatory ethics and practices of crisis mapping. *ACME: An International E-Journal for Critical Geographies, 15*(1), 207–229.
Brown, G. (2012). Public participation GIS (PPGIS) for regional and environmental planning: Reflections on a decade of empirical research. *URISA Journal, 25*(2), 7–18.
Brown, G. (2016). A review of sampling effects and response bias in internet participatory mapping (PPGIS/PGIS/VGI). *Transactions in GIS*. http://dx.doi.org/10.1111/tgis.12207.
Brown, G., Donovan, S., Pullar, D., Pocewicz, A., Toohey, R., & Ballesteros-Lopez, R. (2014). An empirical evaluation of workshop versus survey PPGIS methods. *Applied Geography, 48*, 42–51.
Brown, G., & Fagerholm, N. (2015). Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. *Ecosystem Services, 13*, 119–133.
Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography, 46*, 122–136.
Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC). (2015). *Southern Australia seasonal bushfire outlook 2015-16: November update*. Retrieved 25 March 2016 from http://www.bnhcrc.com.au/hazardnotes/12.
Cavallo, S., Lynch, J., & Scull, P. (2014). The digital divide in citizen-initiated government contacts: A GIS approach. *Journal of Urban Technology, 21*(4), 77–93.
Chuvieco, E., & Congalton, R. G. (1989). Application of remote sensing and geographic information systems to forest fire hazard mapping. *Remote sensing of Environment, 29*(2), 147–159.
Cinnamon, J., & Schuurman, N. (2013). Confronting the data-divide in a time of spatial turns and volunteered geographic information. *GeoJournal, 78*(4), 657–674.
Corbett, J. (2003). *Good practices in participatory mapping: A review prepared for the international fund for Agricultural development (IFAD)*.
Corbett, J. M., & Keller, C. P. (2005). An analytical framework to examine empowerment associated with participatory geographic information systems (PGIS). *Cartographica: The International Journal for Geographic Information and Geovisualization, 40*(4), 91–102.
Council of Australian Governments (COAG). (2011). *National Strategy for disaster resilience: Building our nation's resilience to disasters*. Retrieved 25 March 2016 from https://www.coag.gov.au/sites/default/files/national_strategy_disaster_resilience.pdf.
Country Fire Authority (CFA). (2016). *Community fireguard*. Retrieved 25 March 2016 from http://www.cfa.vic.gov.au/plan-prepare/community-fireguard/.
Crawford, K., & Finn, M. (2015). The limits of crisis data: Analytical and ethical challenges of using social and mobile data to understand disasters. *GeoJournal, 80*(4), 491–502.
Curtis, S., Gesler, W., Smith, G., & Washburn, S. (2000). Approaches to sampling and case selection in qualitative research: Examples in the geography of health. *Social Science & Medicine, 50*, 1001–1014.
Decision Support Analytics (DSA). (2016). *Bushfire-ready neighbourhoods round 1 2014-2016 evaluation report*. Report compiled for Tasmania Fire Service, June 2016.
DeLyser, D., & Sui, D. (2014). Crossing the qualitative-quantitative chasm III: Enduring methods, open geography, participatory research, and the fourth paradigm. *Progress in Human Geography, 38*(2), 294–307.
Department of Premier and Cabinet (DPAC). (2013). *Tasmanian bushfires inquiry report* (p. 2013). Retrieved 25 March 2016 from http://www.dpac.tas.gov.au/divisions/osem/2013_tasmanian_bushfires_inquiry_report/2013_tasmanian_bushfires_inquiry_report.
Dunlop, P. D., McNeill, I. M., Boylan, J. L., Morrison, D. L., & Skinner, T. C. (2014). Preparing… for what? Developing multi-dimensional measures of community wildfire preparedness for researchers, practitioners and households. *International Journal of Wildland Fire, 23*(6), 887–896.
Dunn, C. E. (2007). Participatory GIS—a people's GIS? *Progress in Human Geography, 31*(5), 616–637.
Elwood, S. (2006). Critical issues in participatory GIS: Deconstructions, reconstructions, and new research directions. *Transactions in GIS, 10*(5), 693–708.
Elwood, S., Goodchild, M. F., & Sui, D. (2012). Researching volunteered geographic information: Spatial data, geographic research, and new social practice. *Annals of the Association of American Geographers, 102*(3), 571–590.
Emergency Management Australia (EMA). (2011). *EMA disasters database from Australian government*. Attorney-General's Department. https://www.ag.gov.au/EmergencyManagement/.
Eriksen, C., & Prior, T. (2013). Defining the importance of mental preparedness for risk communication and residents well-prepared for wildfire. *International Journal of Disaster Risk Reduction, 6*, 87–97.
Ferster, C. J., & Coops, N. C. (2014). Assessing the quality of forest fuel loading data collected using public participation methods and smartphones. *International Journal of Wildland Fire, 23*, 585–590.
Fox-Hughes, P., Harris, R. M. B., Lee, G., Jabour, J., Grose, M. R., Remenyi, T. A., et al. (2015). *Climate futures for Tasmania future fire danger: The summary and technical report*. Hobart, Tasmania: Antarctic Climate & Ecosystems Cooperative Research Centre. Retrieved 10 May 2016 from http://acecrc.org.au/wp-content/uploads/2015/12/Report_CFT_Future-Fire-Technical-Report_2015_web.pdf.
Frandsen, M. (2012). *Promoting community bushfire preparedness: Bridging the theory–practice divide*. Doctoral dissertation. University of Tasmania. Retrieved 25 March 2016 from http://eprints.utas.edu.au/15309/.
Gaillard, J. C., & Maceda, E. A. (2009). Participatory three-dimensional mapping for disaster risk reduction. *Participatory Learning and Action, 60*, 109–118.
Gargano, L. M., Caramanica, K., Sisco, S., Brackbill, R. M., & Stellman, S. D. (2015). Exposure to the World Trade Center disaster and 9/11-related post-traumatic stress disorder and household disaster preparedness. *Disaster Medicine and Public Health Preparedness, 9*(06), 625–633.
Genovese, E., & Roche, S. (2010). Potential of VGI as a resource for SDIs in the North/South context. *Geomatica, 64*(4), 439–450.
Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal, 69*(4), 211–221.
Goodchild, M. F., & Glennon, J. A. (2010). Crowdsourcing geographic information for disaster response: A research frontier. *International Journal of Digital Earth, 3*(3), 231–241.
Granell, C., & Ostermann, F. O. (2016). Beyond data collection: Objectives and methods of research using VGI and geo-social media for disaster management. *Computers, Environment and Urban Systems, 59*, 231–243.
Griffith, D. (2013). Establishing qualitative geographic sample size in the presence of spatial autocorrelation. *Annals of the Association of American Geographers, 103*(5), 1107–1122.
Gupta, A., & Kumaraguru, P. (2012). Credibility ranking of tweets during high impact events. In *Proceedings of the 1st workshop on privacy and security in online social media*. ACM.
Haklay, M., Basiouka, S., Antoniou, V., & Ather, A. (2010). How many volunteers does it take to map an area well? The validity of Linus' law to volunteered geographic information. *The Cartographic Journal, 47*(4), 315–322.
Hausman, A., Hanlon, A., & Seals, B. (2007). Social capital as a mediating factor in emergency preparedness and concerns about terrorism. *Journal of Community Psychology, 35*(8), 1073–1083.
Haworth, B. (2016). Emergency management perspectives on volunteered geographic information: Opportunities, challenges and change. *Computers, Environment and Urban Systems, 57*, 189–198.
Haworth, B., & Bruce, E. (2015). A review of volunteered geographic information for disaster management. *Geography Compass, 9*(5), 237–250.
Haworth, B., Bruce, E., & Middleton, P. (2015). Emerging technologies for risk reduction: Assessing the potential use of social media and VGI for increasing community engagement. *The Australian Journal of Emergency Management, 30*(3), 36–41.
Hung, K., Kalantari, M., & Rajabifard, A. (2016). Methods for assessing the credibility of volunteered geographic information in flood response: A case study in Brisbane, Australia. *Applied Geography, 68*, 37–47.
Jayathilake, D., Perera, S., Bandara, S., Wanniarachchi, H., & Herath, L. (2011). A technical insight into community geographic information systems for smartphones. In *International conference on computer applications and industrial electronics (ICCAIE 2011)*.
Jing, L., Liu, X., & Gang, L. (2013). Public participatory risk mapping for community-based urban disaster mitigation. *Applied Mechanics and Materials, 380–384*, 4609–4613.
Jordan, G. (2002). GIS for community forestry user groups in Nepal: Putting people before the technology. In W. J. Craig, T. M. Harries, & D. Weiner (Eds.), *Community participation and geographic information systems* (pp. 232–245). New York: Taylor & Francis.
Keane, R. E., Drury, S. A., Karau, E. C., Hessburg, P. F., & Reynolds, K. M. (2010). A method for mapping fire hazard and risk across multiple scales and its application in fire management. *Ecological Modelling, 221*(1), 2–18.
Latonero, M., & Shklovski, I. (2011). Emergency management, Twitter, and social media evangelism. *International Journal of Information Systems for Crisis Response and Management, 3*(4), 1–16.
Liu, S., & Palen, L. (2010). The new cartographers: Crisis map mashups and the emergence of neogeographic practice. *Cartography and Geographic Information Science, 37*(1), 69–90.
MacDougall, C., Gibbs, L., & Clark, R. (2014). Community-based preparedness programmes and the 2009 Australian bushfires: Policy implications derived from applying theory. *Disasters, 38*(2), 249–266.
Mayoux, L. (2006). Quantitative, qualitative or participatory? Which method, for what and when? In V. Desai, & R. Potter (Eds.), *Doing development research* (pp. 115–129). London: SAGE Publications.
McCall, M. K., Martinez, J., & Verplanke, J. (2015). Shifting boundaries of volunteered geographic information systems and modalities: Learning from PGIS. *ACME: An International E-Journal for Critical Geographies, 14*(3), 791–826.
McGee, T. (2011). Public engagement in neighbourhood level wildfire mitigation and preparedness: Case studies from Canada, the US and Australia. *Journal of Environmental Management, 92*(10), 2524–2532.
McLennan, J., Elliott, G., Omodei, M., & Whittaker, J. (2013). Householders' safety-related decisions, plans, actions and outcomes during the 7 February 2009 Victorian (Australia) wildfires. *Fire Safety Journal, 61*, 175–184.
Meier, P. (2012). Crisismapping in action: How open source software and global

volunteer networks are changing the world, one map at a time. *Journal of Map and Geography Libraries, 8*, 89–100.
Murphy, B. L. (2007). Locating social capital in resilient community-level emergency management. *Natural Hazards, 41*, 297–315.
Norris, P. (2001). *Digital divide?: Civic engagement, information poverty, and the internet worldwide*. New York: Cambridge University Press.
Norris, F., Sherrieb, K., & Pfefferbaum, B. (2011). Community resilience: Concepts, assessment, and implications for interventions. In S. M. Southwick, B. T. Litz, D. Charney, & M. J. Friedman (Eds.), *Resilience and mental health: Challenges across the lifespan*. Cambridge, UK: Cambridge University Press.
Ostermann, F., & Spinsanti, L. (2011). A conceptual workflow for automatically assessing the quality of volunteered geographic information for crisis management. In *Proceedings of the 14th AGILE international conference on geographic information science, Utrecht, 18–22 April*.
Palen, L., & Liu, S. B. (2007). Citizen communications in crisis: Anticipating a future of ICT-supported public participation. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 727–736). San Jose, California, USA: ACM, 1240736.
Paton, D. (2003). Disaster preparedness: A social-cognitive perspective. *Disaster Prevention and Management, 12*, 210–216.
Penman, T. D., Eriksen, C. E., Blanchi, R., Chladil, M., Gill, A. M., Haynes, K., et al. (2013). Defining adequate means of residents to prepare property for protection from wildfire. *International Journal of Disaster Risk Reduction, 6*, 67–77.
Penman, T. D., Eriksen, C. E., Horsey, B., & Bradstock, R. A. (2016). How much does it cost residents to prepare their property for wildfire? *International Journal of Disaster Risk Reduction, 16*, 88–98.
Perrin, A. (2015). *Social media usage: 2005-2015*. PewResearchCenter, Internet, Science & Tech. Retrieved 11 April 2016 from http://www.pewinternet.org/2015/10/08/social-networking-usage-2005-2015/.
Poushter, J. (2016). *Smartphone ownership and internet usage continues to climb in emerging economies*. PewResearchCenter, Global Attitudes & Trends. Retrieved 11 April 2016 from http://www.pewglobal.org/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/.
Prior, T. (2010). *Householder bushfire preparation: Decision-making and the implications for risk communication*. PhD thesis. Hobart: School of Psychology, University of Tasmania.
Ricker, B., Schuurman, N., & Kessler, F. (2015). Implications of smartphone usage on privacy and spatial cognition: Academic literature and public perceptions. *GeoJournal, 80*(5), 637–652.
Rousselot, J. (2015). *Photo slideshow: The local volunteers behind Nepal's aid*. Retrieved 25 March 2016 from http://newirin.irinnews.org/extras/2015/5/2/in-pictures-nepals-local-volunteers.
Sandelowski, M. (1995). Focus on qualitative methods: Sample size in qualitative research. *Research in Nursing and Health, 18*, 179–183.
Scanlon, J., Helsloot, I., & Groenendaal, J. (2014). Putting it all together: Integrating ordinary people into emergency response. *International Journal of Mass Emergencies and Disasters, 32*(1), 43–63.
Scassa, T. (2013). Legal issues with volunteered geographic information. *The Canadian Geographer, 57*(1), 1–10.
Senaratne, H., Mobasheri, A., Ali, A. L., Capineri, C., & Haklay, M. (2016). A review of volunteered geographic information quality assessment methods. *International Journal of Geographical Information Science*, 1–29. http://dx.doi.org/10.1080/13658816.2016.1189556.
Shanley, L. A., Burns, R., Bastian, Z., & Robson, E. S. (2013). Tweeting up a storm: The promise and perils of crisis mapping. *Photogrammetric Engineering and Remote Sensing, 79*(10), 865–879.
Sieber, R. E., & Haklay, M. (2015). The epistemology(s) of volunteered geographic information: A critique. *Geo: Geography and Environment, 2*(2), 122–136.
Sui, D., Goodchild, M. F., & Elwood, S. (2013). Volunteered geographic information, the exaflood, and the growing digital divide. In D. Z. Sui, S. Elwood, & M. F. Goodchild (Eds.), *Crowdsourcing geographic knowledge: Volunteered geographic information (VGI) in theory and practice* (pp. 1–12). Berlin: Springer.
Tasmania Fire Service (TFS). (2014). *Bushfire ready neighbourhoods*. Retrieved 25 March 2016 from http://www.bushfirereadyneighbourhoods.tas.gov.au/.
Taylor, M., Wells, G., Howell, G., & Raphael, B. (2012). The role of social media as psychological first aid as a support to community resilience building. *The Australian Journal of Emergency Management, 27*(1), 20–26.
Tulloch, D. (2007). Many, many maps: Empowerment and online participatory mapping. *First Monday, 12*(2). Retrieved 25 March 2016 from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1620.
Tulloch, D. L. (2008). Is VGI participation? From vernal pools to video games. *GeoJournal, 72*(3–4), 161–171.
United Nations International Strategy for Disaster Reduction (UNISDR). (2015). *Sendai framework for disaster risk reduction 2015-2030*. Retrieved 25 March 2016 from http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf.
Villemure, M., Wilson, T. M., Bristow, D., Gallagher, M., Giovinazzi, S., & Brown, C. (2012). *Liquefaction ejecta clean-up in Christchurch during the 2010-2011 earthquake sequence*. Retrieved 25 March 2016 from http://ir.canterbury.ac.nz/bitstream/handle/10092/7285/12641199_Villemure%20et%20al.%202012%20-%20NZSEE%20Paper131_15042012.pdf?sequence=1.
Whittaker, J., Eriksen, C. E., & Haynes, K. (2016). Gendered responses to the 2009 Black Saturday bushfires in Victoria, Australia. *Geographical Research, 54*(2), 203–215.
Whittaker, J., Haynes, K., Handmer, J., & McLennan, J. (2013). Community safety during the 2009 Australian 'Black Saturday' bushfires: An analysis of household preparedness and response. *International Journal of Wildland Fire, 22*(6), 841–849.
Whittaker, J., McLennan, B., & Handmer, J. (2015). A review of informal volunteerism in emergencies and disasters: Definition, opportunities and challenges. *International Journal of Disaster Risk Reduction, 13*, 358–368.