International Journal of Disaster Risk Reduction 30 (2018) 5–17

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Sending a message: How significant events have influenced the warnings landscape in Australia

Linda Anderson-Berry[a], Tamsin Achilles[b], Shannon Panchuk[a], Brenda Mackie[c], Shelby Canterford[d], Amanda Leck[e], Deanne K. Bird[f,g,*]

[a] Bureau of Meteorology Australia, Australia
[b] Victoria State Emergency Service, Australia
[c] Emergency Management Victoria, Australia
[d] GeoScience Australia, Australia
[e] Australasian Fire and Emergency Service Authorities Council, Australia
[f] Faculty of Life and Environmental Sciences, University of Iceland, Iceland
[g] Monash University Disaster Resilience Initiative, Monash University, Australia

ARTICLE INFO

Keywords:
Total Warning System
Impact forecasting
Risk-based warnings
Community engagement
Communicating uncertainty
Disaster resilience

ABSTRACT

The Bureau of Meteorology has a mandate to issue warnings for weather and climate events that are likely to result in harm and loss. This service has been delivered in an end-to-end (science to service) context and warnings messages have typically been crafted to describe the current and predicted future state of the environment and recommended protective actions. However, the warnings landscape is evolving and Australian governments and emergency management agencies are adopting rapidly diversifying roles in a range of warnings processes. This evolution coincides with the shift in international strategies: from the mitigation and crisis management approach to the emphasis on building community resilience. Following a number of severe weather-related events that resulted in serious losses a series of Australian inquiries, reviews and social research investigated warnings efficacy. This included the National Review of Warnings and Information for Australia, with a recommendation suggesting that a Total Warning System concept be more formally considered across multiple hazards, rather than just flood, as it currently stands. Consequently, Australian warnings agencies are embracing a more people-centred approach recognising the need for messages to include detail of likely impact alongside an implied level of risk. Thus, developing capability to deliver impact forecasting and risk-based warnings services in a multi (natural) hazard context. With a key focus on flood, fire and tropical cyclone, this paper reviews international and national warnings policy documents and social research and explores the evidence-based evolution of warning services with respect to the Total Warning System concept.

1. Introduction

There have been significant advances to Australia's hazard warning systems which can be conceptualised as a transition from a crisis response model to one of community preparedness, disaster mitigation and more recently, disaster risk reduction (DRR) [99]. National and international events (Fig. 1) and, associated social research has driven this change by critically highlighting the need to: communicate warning messages in terms of likely impact, enhance awareness of risk and uncertainty and, increase preparedness prior to an emergency. The central goal of this change is to improve public risk-based decision making in response to emergency warnings [40,98,99]. To achieve this, the National Review of Warnings and Information for Australia considers:

> 'There is merit in the 'total warning system' concept, already adopted by flood response agencies, being more formally considered across other hazards in the development of future warning frameworks ([40]; p.10).'

The Total Flood Warning System (Fig. 2) is uniquely the only formally documented Total Warning System in Australia. Manual 21 [5] describes the Total Warning System concept as broadly about discovering and applying the best hazard related science and technology to understand and describe the current and predicted future state of the environment as it relates to a specific threat. This system supports the Bureau of Meteorology (the Bureau), who is responsible for monitoring

* Corresponding author at: University of Iceland, Iceland.
E-mail address: deanne.bird@gmail.com (D.K. Bird).

https://doi.org/10.1016/j.ijdrr.2018.03.005
Received 18 August 2017; Received in revised form 1 March 2018; Accepted 1 March 2018
Available online 06 March 2018
2212-4209/ Crown Copyright © 2018 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/BY-NC-ND/4.0/).

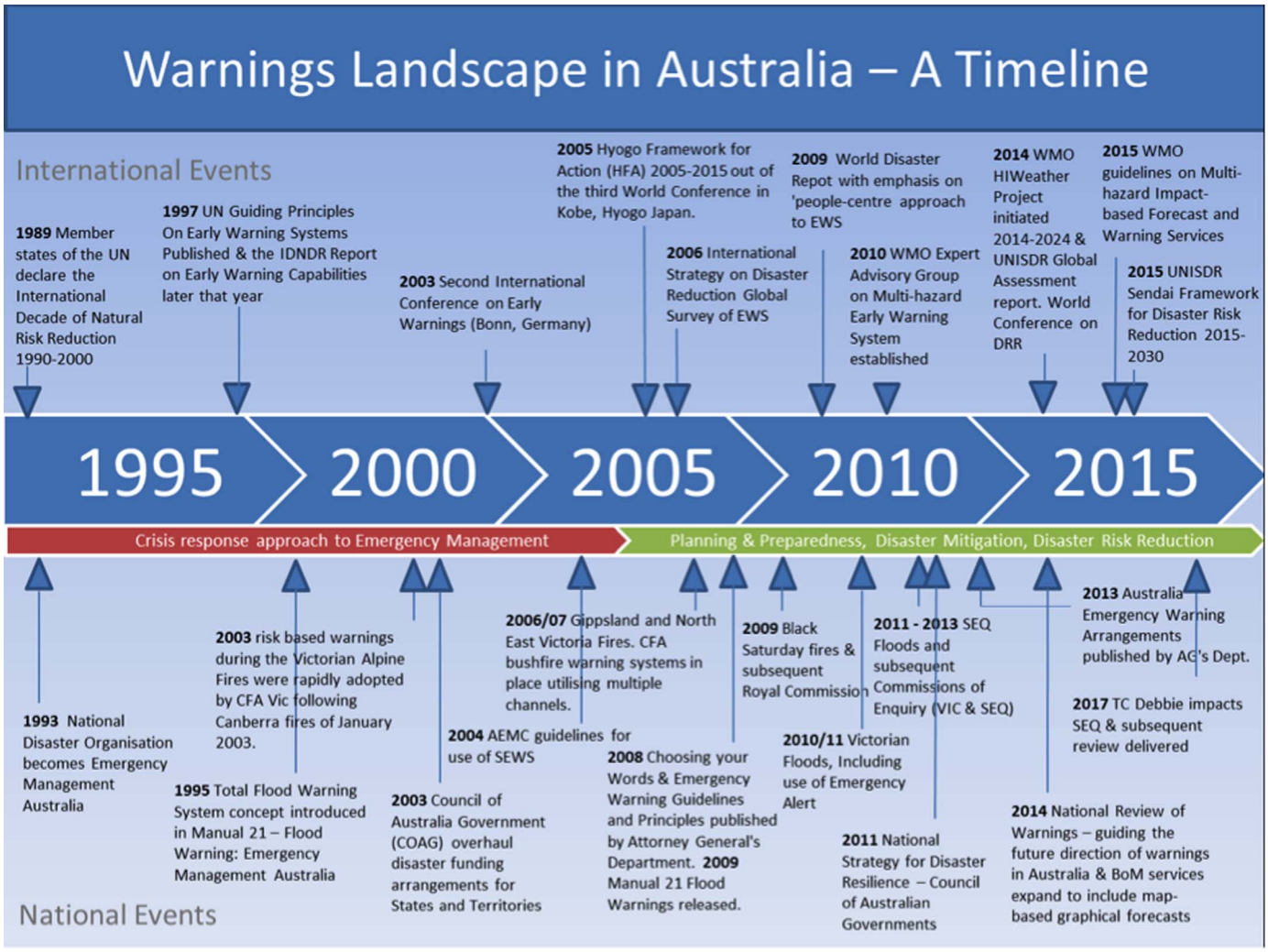

Fig. 1. Warnings landscape in Australia, significant national and international events and influences since 1989.

and prediction, in issuing timely flood warnings at serviced locations[1] for many of the flood prone communities across Australia. Bureau warnings are then interpreted by responsible warning agencies, supplemented with additional impact information and recommended precautionary actions. Additional warnings are then communicated by these agencies via any and all appropriate channels, in relevant formats, to end users [5]. Agencies aim to ensure end users receive timely flood warnings that are understood and trusted to assist people make timely decisions to support their safety and wellbeing. Post event reviews are then recommended to assess the warning products efficacy, and elements of the Total Flood Warning System to ensure continual improvement of the system [5].

However, recent post event reviews following significant events in Australia have highlighted failures within the warning systems, not just for flood, but also for other hazards, such as bushfire and tropical cyclone. This paper considers these deficiencies and explores how the Total Warning System concept might be achieved across all hazards. In doing so, this paper enhances our understanding of the critical factors that need to be considered when developing future impact forecast and risk-based warning systems and thus, will guide improvements to current systems.

First, this paper captures the evolution towards impact forecast and risk-based warning systems with respect to a Total Warning System concept, by exploring the warnings landscape in Australia in consideration of recent key international strategies and national policy developments. To further highlight the drive towards the Total Warning System concept and elements that require greater focus, the next sections consider the complexities of flood, fire and tropical cyclone warnings in relation to learnings from specific Australian events over the past decades. Based on this analysis, the paper presents the critical components of a Total Warning System and considers where impact and risk information should be incorporated. The paper concludes with mention of various initiatives, by and for Australian warning agencies that will contribute to the transition to impact forecast and risk-based warning systems and the potential for adoption of a Total Warning System concept across all hazards.

The applied research method for this study has taken place through a review of international and national warnings policy documents and the social research across multiple hazards, with a key focus on flood, fire and tropical cyclone. After heatwaves, these three hazards are the most deadly [31] in Australia and the inherent uncertainties in forecasting and warning, compound the challenges of effective communication.

National weather services world wide, together with their partners in emergency management and national governments, are transitioning towards developing impact forecasting and risk based warnings systems. The World Meteorological Organisation supports and promotes this move. While most of the findings and learnings arising from the

[1] Serviced locations exist for most rivers in Australia, which have flood warning infrastructure installed (including rainfall and river height gauges), to support issuing of predictive flood warnings aligned to predetermined flood class levels [25].

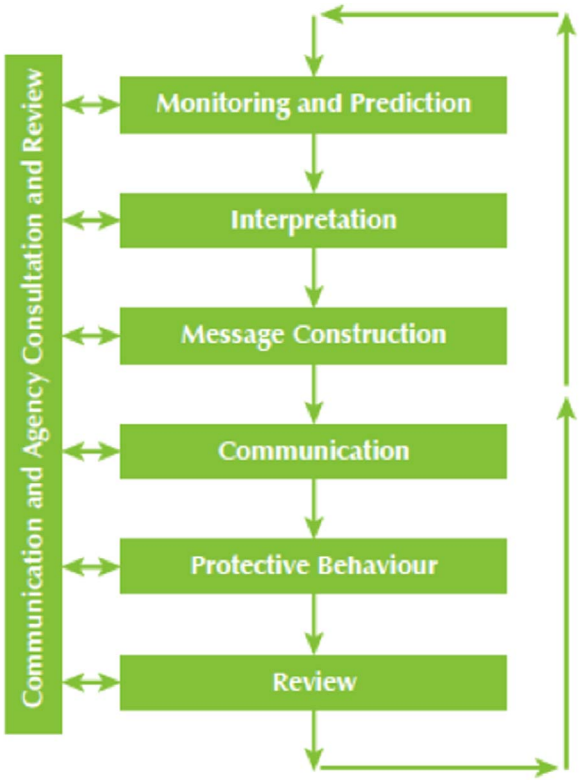

Fig. 2. The components of the Total Flood Warning System (TFWS) [5].

various case studies throughout this paper are relevant internationally the focus of the discussion below is the Australian context.

2. The warnings landscape in Australia

To provide insight into the development of the warnings landscape in Australia, this section begins broadly by identifying key international strategies that Australia has helped influence, and has been influenced by. The following section describes developments in various national policies that have contributed to the evolution of warnings across the nation.

2.1. Key international strategies

The International Decade for Natural Disaster Reduction (IDNDR) from 1990 to 2000 resulted in a rich body of literature on the topic of early warning systems which emphasised the need to shift away from a 'crisis and contingency' approach to that of DRR through all stages of the risk management process [44,57]. During and following the IDNDR, several global strategies were produced including the *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters* (2005). This framework emphasised the implementation of 'people-centred' early warning systems as of key importance for supporting '…effective operations by disaster managers and other decision makers' [89, p.9].

More recently, governments and delegations attending the 2015 UN World Conference in Sendai, Japan declared the Sendai Framework for DRR 2015–2030 as a leading plan for reducing loss from disasters and building community resilience globally. The plan (global target number seven) expresses a need to increase availability and accessibility of disaster risk information through Multi-Hazard Early Warning Systems, [90, p.12]. Australia has been an active participant in these global initiatives including national efforts to tangibly transform warning and disaster management practices into effective DRR models which are in line with the Sendai framework [2].

Shortly after the 2015 Sendai conference, the World Meteorological Organisation (WMO) released guidelines to assist meteorological services to take a more people-centred approach, recommending a shift to impact-based forecasts and risk-informed warnings [98]. The WMO advocate that, in addition to well-forecasted events and accurate warnings, services need to communicate what the impact of a hazard (or multiple hazards) might be to an individual or community at risk. This means replacing forecasts and warnings that state hazard only e.g., 'wind gusts of over 100 km per hour (kmph) expected', with ones that incorporate impact e.g., 'severe thunderstorms with wind gusts over 100 kmph likely to result in damage to trees and power lines' [98, p.6]. The guidelines acknowledge the need for disaster impact forecasts and risk-based information because, while stakeholders, individuals and communities may realise 'what the weather might be, there is a frequent misunderstanding about what the weather might do' [98, p.2].

The WMO also highlights the critical importance of partnerships between stakeholders and the public, especially in situations where emergency services are mandated with issuing community warnings that include local information about impact and exposure e.g., 'extensive traffic delays in Kensington may occur due to the risk of large trees downing power lines and blocking roads as a result of severe thunderstorms' [98, p.14]. They also outline the need to address inherent forecast uncertainty, and its link to exposure and vulnerability in order to quantify risk associated to the likely impact of weather [98].

2.2. National policy developments

Coincident with these international strategies, the Australian and New Zealand Emergency Management Committee (ANZEMC) initiated a National Review of Warnings and Information (herein called 'the Review; [40]) in response to the 2009 Bushfire Royal Commission and other inquiries following the 2010–11 Queensland and Victorian Floods and Severe Tropical Cyclones Larry and Yasi in 2006 and 2011, respectively. The Review was conducted in the context of warnings being an integral component of emergency management and effective hazard warnings processes being essential to building community disaster resilience [40].

The Review was a 'landmark' in that for the first time it provided an opportunity to rigorously investigate how warnings and information were provided across a multi-hazard, national sphere. The findings of the Review were widely regarded and endorsed by the Steering Committee, together with key decision makers. For example, the Australasian Fire and Emergency Services Authorities Council (AFAC) endorsed the establishment of a National Working Group for Public Information and Warnings to consider the warnings environment holistically and explore strengths, challenges, opportunities and good practice [3].

In scoping the Review, representatives from across the emergency management sector agreed that both warnings about hazards (such as those provided by the Bureau) and warnings about potential impact of an incident (such as those typically provided by emergency services and other statutory authorities), should be considered [40]. The fact that a distinction between the two is articulated is interesting on many levels for the Bureau and emergency services, and from a community perspective. Firstly, it demonstrates a lack of shared understanding among stakeholders of what a 'warning' is and, more importantly, it implies in the review, that for completeness, a national warnings capability needs to include information about the hazard and the potential impact. However, the Review does not go into detail on how this might be achieved or why this is important. Further, based on this assumption, it could reasonably be concluded that a partnership between weather services, emergency services, statutory authorities and diverse and at-risk communities is essential to build this capability [45].

From the Bureau's perspective, the primary purpose of warnings is to provide adequate information about an impending (hazard related) peril to enable defensive action. From the emergency services'

perspective, response agencies are best placed to provide warnings about the likely impact of the hazard to communities in an effort to enhance preparedness and reduce harm. This is true for all hazards across all levels of social aggregation and time scales. This is a responsibility that is defined in legislation and through arrangements that are unique to each state and territory [6]. These arrangements are pursued in operations through multi-hazard early warning systems [99].

The Review calls for greater consistency in the development of warnings frameworks across jurisdictions and across all hazards, with frameworks remaining flexible enough to accommodate the nuances in warning for the various hazards experienced in Australia. Therefore, the need for evidence-based change is highlighted to ensure that the tailored and targeted information needs of communities are not compromised with the merging of warnings frameworks and protocols. Further, with the call for agencies to formally consider using the Total Warning System concept in the development of future warning frameworks, the Review draws an explicit connection between community preparedness and how it influences effective response to warnings. Interestingly, the Total Flood Warning System, as it is currently described within Manual 21 [5], does not incorporate community preparedness as a key element. Instead, Manual 21 limits recommendations to engagement of key community members or groups to inform all stages of the Total Flood Warning System and focuses on community education campaigns.

3. The complexities of warnings in Australia

To provide greater context to the developments in national policies of the past decades, the following section reviews the complexities of flood, bushfire and tropical cyclone warnings with reference to social research that has informed the abovementioned inquiries.

3.1. Flood

Australia is commonly known to be the driest inhabited continent on earth [94]. What is less well known is that floods are the second most deadly hazard in Australia, following heatwave [31], and the most expensive hazard for the Australian community [91]. It may be argued that many Australians do not consider flooding to be a significant threat to life, demonstrated by risk taking behaviour such as driving through and recreating in floodwater, which has had disastrous consequences [51].

As the population of Australia continues to grow and diversify, housing expands further across floodplains. Also enhancing the populations' vulnerability is the impact of climate change with the IPCC [56] predicting an increase in the frequency and severity of floods. Given these factors, it is imperative that the community receives high quality flood warnings that are community centric, and are designed to overcome barriers to effective communication of warnings and motivate protective action [45].

Many flood prone communities around Australia are supported by the Total Flood Warning System (see Fig. 2) [5], where warnings products detailing the hazard and associated risk are triggered by real-time and predicted flood heights. Relevant government agencies in each State and Territory enhance existing warnings with information about the likely impact and recommended protective action to engender effective decision-making by the community. The process is completed with a review of the Total Flood Warning System or components of it to identify any failings and areas for improvement [15,5].

Post event reviews in Australia have contributed to the continual evolution of the Total Flood Warning System since the first publication of practitioner guidelines in 1995. Most noteworthy are the inquiries and social research that was undertaken after the Queensland and Victorian floods in 2010–11. In Queensland, flooding resulted in 33 confirmed deaths and '*over 78% of the State declared a disaster zone* [76]'. In Victoria, over one third of the State was affected, with record flood levels being recorded in many communities [32]. Post event reviews of these events identified failings with respect to flood warning dissemination, timeliness, accessibility and tailoring of warnings to meet community needs alongside recommendations on how to address these issues [32,76].

Risk perception as an influencer of warning recipient's response [45] was highlighted as a gap in both Queensland and Victoria due to potential lack of education and engagement of the community with respect to their flood risk [32,76]. Canterford et al. [28] found risk perception was a key determinant of the community's ability to respond to warnings, where '*10% [of respondents] heard a warning but thought it was not relevant to them* [28, p.2]'. While it is acknowledged that there are a broad range of factors that may influence a recipient's response to warnings [36,45,71,72,74], these findings support social research that has shown risk perception can act as a barrier to warning messages being accepted, understood and personalised (e.g. [71]). These are critical components of the highly complex and nuanced decision making process during emergencies [62,78,79].

Interestingly, social media was accessed as a reliable source for personalised information during the 2010–11 events. Through Twitter and various community-run Facebook groups, users posted official warning information from trusted sources complemented with more personalised, local information crowdsourced from other users, e.g. real-time updates of road closures [27,8]. The fact that this occurred highlighted that the public questioned the relevancy of official warnings in terms of providing the most current and useful information. In some instances, timely official information was lacking and when it was received, it often did not meet users' needs [9]. Despite potential risks associated with the quality of information on social media, users self-moderated warning information to ensure that only the most up-to-date and accurate information was shared [27,8]. This demonstrates a high degree of social capital in affected communities, which, if harnessed respectfully, can provide practitioners with an opportunity to meaningfully engage across community networks to build flood resilience through preparedness activities [37].

Greater focus on community education with respect to flood risk and greater engagement of the community to inform the development of tailored warnings to meet community needs were common recommendations of post event reviews in both states [32,76]. While a number of community education activities such as the FloodSafe[2] program, continue to evolve since the 2010–11 floods, the emergency services have been embracing a greater understanding and appreciation of the importance of community engagement in flood planning and preparedness. This forms part of a broader sector wide shift with a greater emphasis of emergency service volunteer roles in community engagement activities, evidenced by various initiatives, including the Community Engagement Forums in Victoria [92]. It is critical, however, that the importance of community engagement is recognised and the processes of engagement are adequately resourced to ensure its effectiveness in enhancing community flood resilience [41,93].

Despite these efforts, similar failures in the dissemination of warnings and public compliance to them were identified in northern New South Wales following floods resulting from ex-Tropical Cyclone Debbie in March 2017. Underlying and recurrent themes emanating from post-impact surveying were the need for locally specific information and the requirement to tap into local knowledge and expertise to inform warnings messages – all of which can be accomplished through effective community engagement. Other points of note included:

- *The timing of evacuation warnings and orders was an important issue, as many received these warnings after roads were already flooded.*
- *Some felt that evacuation orders were too 'bossy' and 'panicky' –*

[2] See, for example: https://www.ses.vic.gov.au/get-ready/floodsafe.

particularly in a context where residents were already 'flooded in' and a culture of sheltering exists [88, p.93].'

These points further highlight the need to personalise and ensure the relevance of warnings with respect to the local context. Given the large number of flood fatalities in Australia associated with driving [51], this also extends to specific warnings for motorists. During flooding in New South Wales in 2015, Gissing et al. [42] observed that the vast majority of motorists (84% of 154) ignored warning signs, instead choosing to drive through floodwater.

Despite these failings, progress has been made by the sector to better understand how to effectively design and implement the Total Flood Warning System including a greater appreciation of how to effectively design flood warnings. Further improvements are anticipated with the very recent publication of '*Developing Total Flood Warning Systems'*, which builds on Manual 21 by providing detailed guidance on the system, but uniquely focuses heavily on elements of successful warning systems and how to meet the needs of the community [38]. Further research is underway with the objective of generating practical guidance to reduce message non-compliance by examining message comprehension and methods for personalising warning messages [87].

A key challenge for emergency services will be to effectively tailor catchment-based scale flood warnings, supported by the Total Flood Warning System, to meet the needs of such a diversifying population. This will likely require a change in practice, potentially through more effective use of communication channels such as social media. The emergency services will also need to remain cognisant of the fact that often the best channels for communicating tailored flood warnings commonly occur when warning information is delivered by family, friends or neighbours [26,28].

3.2. Bushfire

Australia is one of the most bushfire-prone countries in the world. After heatwaves, tropical cyclones and floods, bushfires are the fourth most deadly natural hazard in Australia with 825 fatalities recorded between 1901 and 2011 [12]. Globally between 1978 and 2013, the length of the fire season increased almost 19% reducing opportunities for planned fire risk reduction burning and intensifying pressure on fire fighting resources [53]. In Australia, conditions conducive to harsh fire weather are becoming more frequent which will very likely lead to an increased number of days with extreme fire danger [29], particularly in southern and eastern Australia [34]. Further exacerbating Australia's vulnerability is the growing encroachment of populations in bushfire-prone areas [33,49].

Each Australian state and territory has its own fire authorities, fire advisory practices and procedures. Each bushfire warning system is informed by a Fire Danger Rating system which uses several Fire Danger Indices (FDI), as forecast by the Bureau's data for air temperature, relative humidity, wind speed and drought conditions [20]. Other risk factors such as current fires and local conditions – vegetation and topography – also contribute to the determination of the Fire Danger Ratings.

Prior to 2009, the Fire Danger Rating system typically consisted of: low, moderate, high, very high, and extreme. Also prior to 2009, one of the keystones of the bushfire policy advice was "Prepare, stay and defend, or leave early". However, this policy, and the rationale behind it, was critically contested by the February 2009 Victorian Black Saturday bushfires. The accuracy and quality of bushfire warning systems was consequently put under scrutiny during the 2009 Victorian Bushfires Royal Commission.

While many people effectively stayed and defended their properties or successfully evacuated when threatened, 173 people perished in the Black Saturday bushfires. Whittaker et al. [96] found that many people were not adequately prepared to 'stay and defend' while others waited to take action until the threat was upon them, resulting in late evacuation, defending ill-prepared or undertaking passive shelter.

Based on an analysis of fatality data from 1900 to 2008 (i.e. prior to Black Saturday), Haynes et al. [47] highlighted the inherent complexities of the 'stay and defend or leave early' policy in terms of the ambiguity surrounding 'leave early'. Haynes et al. [47] suggest that people interpreted 'stay and defend or leave early' as wait until it seems dangerous and then evacuate. Tibbits & Whittaker [86] also identified issues of misinterpretations of the 'stay and defend or leave early' policy during the 2003 Victorian bushfires, with people consciously or unconsciously creating a Plan B of late evacuation when staying and defending was untenable.

This 'wait and see' approach was certainly prevalent during the 2009 Black Saturday bushfires with people waiting to see how bad the fires were, waiting until they were under direct threat or waiting for advice from the emergency services [66,95]. McLennan et al. [66] found that people's indecisiveness around when to evacuate was a result of the uncertainty about the severity and proximity of the fires with many people waiting for an external trigger to spark decisive action. That is, people responded when the threat was imminent [67,96]. Whittaker et al. [97] therefore postulate that emergency warnings need to provide more clear and detailed action advice for people that have limited awareness and understanding of bushfire risk.

The 2009 Victorian Bushfires Royal Commission (the Commission) concluded that while the 'central tenets of the stay or go policy remain sound these fires 'severely test the policy and exposed weaknesses in the way it was applied' [85, p.5]. The Commission also clarified 'Leaving early is still the safest option'. Staying to defend a well-prepared, defendable home is also a sound choice in less severe fires, but there needs to be greater emphasis on important qualifications' [85, p.5]. For example, McLennan et al. [68] found that people living in bushfire prone areas are unlikely to accept that the safest plan is to leave early well before a bushfire is imminent due to a strong desire to stay and defend. McLennan et al. therefore recommend '(a) motivating householders intending to stay and defend to undertake systematic risk assessments of their specific property and family member circumstances if threatened by bushfire under a range of fire danger weather conditions; and (b) informing them of the requirements for safe and effective defence under these different threat levels' (2015a; p.43). Furthermore, it is critical that at-risk populations receive timely and accurate information about a fire's speed, location and the direction in which it is travelling [67].

An outcome of the Commission was that Australia adopt a national bushfire warning system in order to provide further detail about the days with the greatest risk to life and property. The recommendation was to split the fire rating that was formerly 'Extreme' into three levels – Severe, Extreme and Catastrophic or Code Red.[3] To address identified weaknesses in the 'Prepare, stay and defend or leave early' policy, the Commission recommended that a national 'Prepare. Act. Survive.' strategy be adopted. Even though messages under the old policy were similar to that of the abovementioned strategy, the Commission advised that the leaving option must be emphasised and that *'any policy must encourage people to adopt the lowest risk option available to them, which is to leave well before a bushfire arrives in the area*' [85]. However, in the event that people decide to stay despite the dangers, core messages must stress the significant levels of preparedness required to successfully defend a property in a fire event [12].

The Commission also recommended significant improvements to risk communication, education and warnings because many people who died were: taken by surprise (unaware of the level of the warnings); overcome by the ferocity of the fire because they did not adequately

[3] 'Code Red' is used in Victoria, and all other states and territories use the rating of 'Catastrophic', see for example: http://www.cfa.vic.gov.au/warnings-restrictions/about-fire-danger-ratings/.
https://www.rfs.nsw.gov.au/plan-and-prepare/fire-danger-ratings.

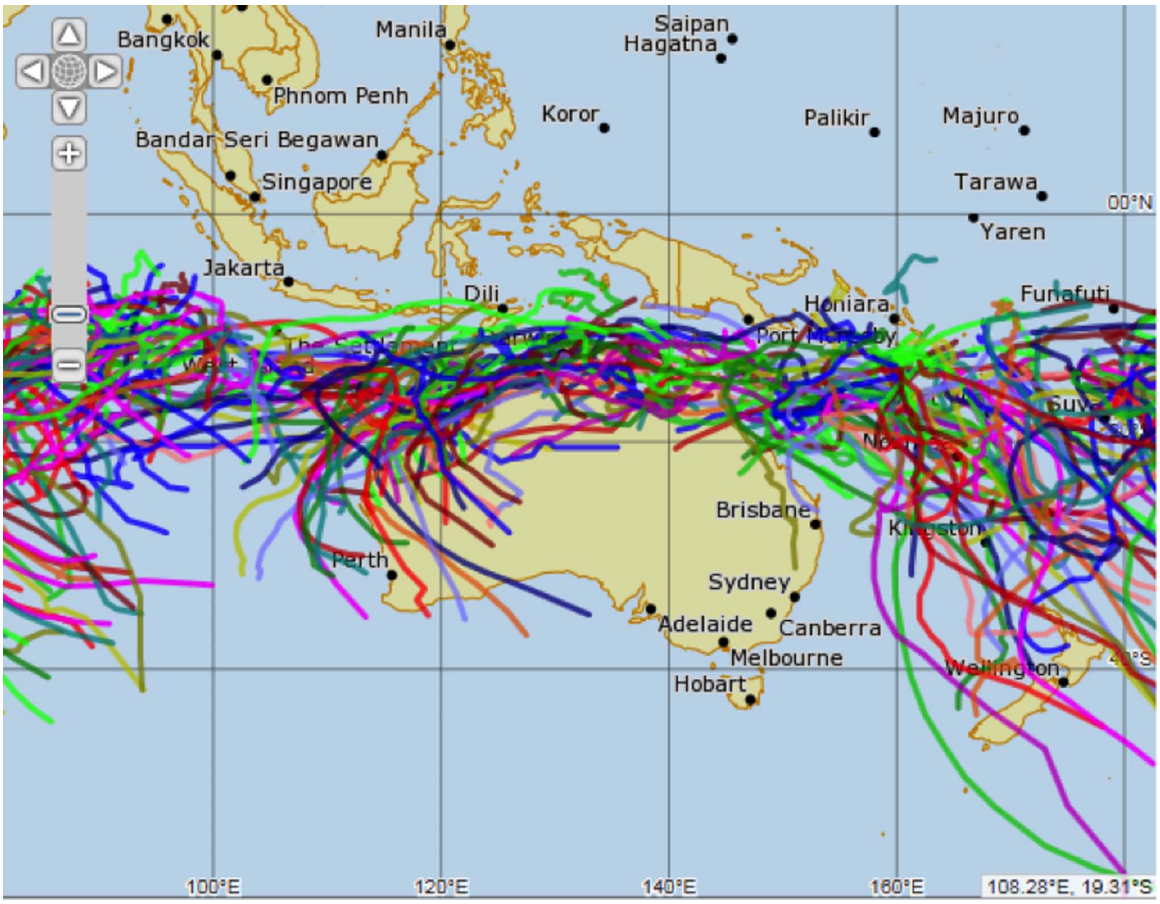

Fig. 3. Tropical cyclone impacts and threats to the Australian region between 1997 and 2016 [21].

understand what the fire danger levels meant for them; and, unaware of the high risk [84]. In response, the Fire Danger Rating System was reviewed and a National Framework for Scaled Advice and Warnings to the Community was developed and agreed upon by all states and territories [1]. As well as the amended Fire Danger Ratings, three levels of warnings with associated actions – Advice; Watch and Act; and, Emergency Warning - was adopted, stressing that people should never wait for an official warning before leaving and that a fire may start rapidly, threatening communities within minutes.

Despite these efforts, however, studies undertaken across multiple States and Territories since its inception reveal continued issues. For example, McLennan et al. [69] found that people impacted by bushfire in New South Wales, Tasmania and Western Australia during 2011–2014 had believed they were not at risk, were unprepared, did not proactively evacuate based on predicted bushfire weather and, adopted a 'wait and see' approach. Furthermore, Haynes and Bird [50] discovered that local residents who were part of the Community Fire Units during the 2013 Blue Mountains bushfires did not know when it was safe to stay and defend or when to evacuate.

Mackie [63] found that people felt they were less at risk (and therefore often ignored warnings) if they had experienced a fire previously and survived, or had been warned over a long period of time about a potential bushfires that then did not happen at all, or in the way it was predicted. This 'prolonged threat' in specific contexts can set up a warning fatigue of sorts. Conversely, with rapid onset fires, the perceived likelihood of the threat is higher, as is the perceived level of danger resulting in higher vigilance and heeding of warnings.

To combat these failings, a new and improved National Fire Danger Rating System is currently being developed for Australia with aim to '*improve community awareness of risk exposure, provide greater scientific accuracy behind decisions, advice and warnings and give communities greater confidence in the information being provided*' [4]. As an initial step, a Fire Behaviour Index prototype is being trialled over the 2017/18-bushfire season. Following this, dedicated social research will be undertaken to:

- *understand community thinking about fire danger ratings, including triggers for response, i.e. what they know, what they think they should do, what they've experienced*
- *determine community vulnerability in relation to fire danger ratings e.g. is fire risk communicated appropriately to the public, are the channels for communicating risk to the public appropriate (fire danger rating meter, government websites, official government social media sites), is the imagery, execution, messaging and tone appropriate, does the fire danger rating meter prompt the desired behaviour, what are the community expectations with fire warnings, what messaging and channels are appropriate for vulnerable sections of society (e.g. CALD, people with disability)?*
- *provide guidance on key messaging that enacts sustained change and appropriate behaviour, including best messaging for vulnerable sections of society*
- *detail what enhancements need to be made from current fire danger rating systems to the new system to better communicate risk and increase confidence in practitioner decision making, i.e. is it only about changing the messaging?*
- *provide a communication model for fire preparedness, including personal indicators, community indicators and agency indicators*
- *nationally agreed communication model and messaging for the system; resulting in clear, consistent and trusted messaging across state/territory borders, and*
- *ultimately, reduce loss of life and enforce sustained, appropriate community behaviour during fire events* ([81]; p.4).

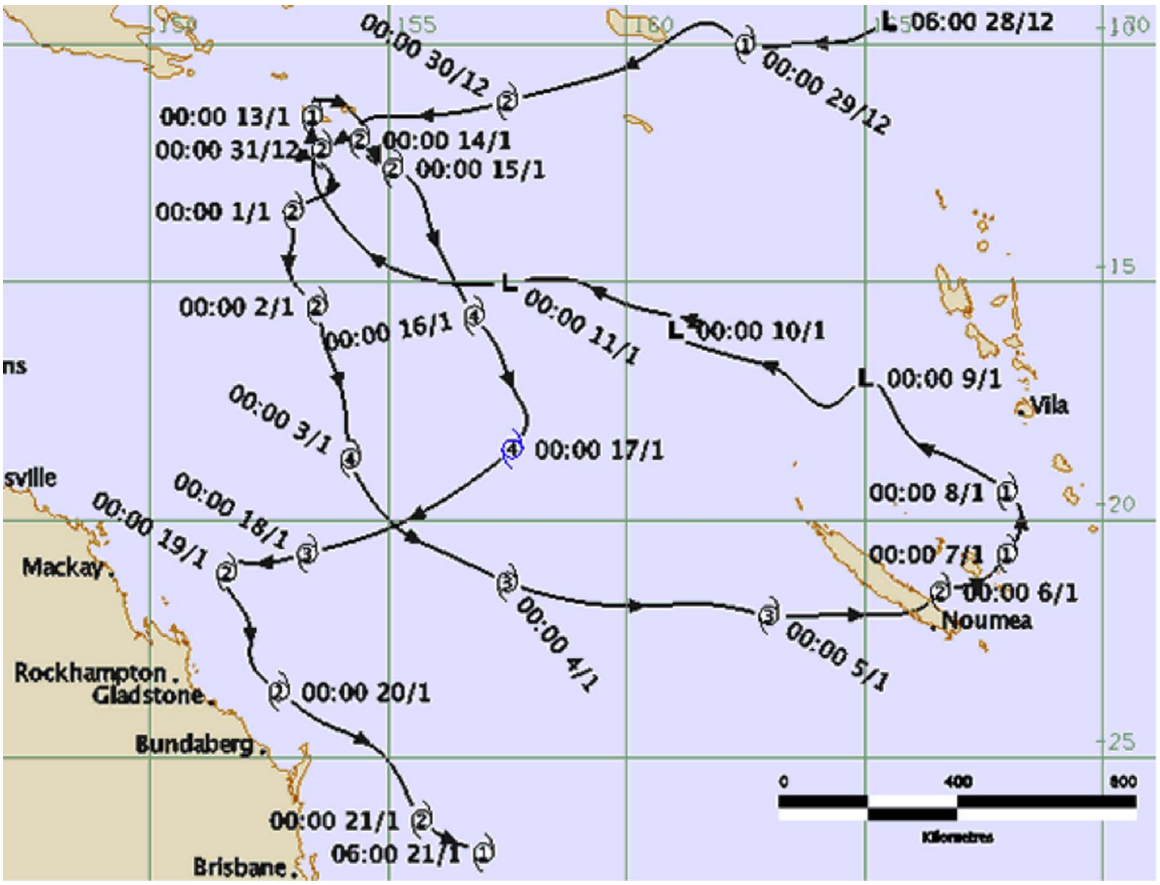

Fig. 4. TC Rewa 1993: demonstrates the uncertain nature of Tropical Cyclone hazards [13].

3.3. Tropical cyclone

The northern tropical regions of Australia is one of the most cyclone prone areas in the world with communities facing annual risk [19]. Approximately 40 Severe Tropical Cyclones (TC) have impacted Australia over the last 20 years (Fig. 3) [21]. Categorised as Category 3, 4 or 5, Severe TC have sustained surface winds of at least 118 kmph and gusts of or exceeding 165 kmph [17].

Interestingly, Australian cyclones display more erratic paths compared to other parts of world (Fig. 4) [22]. This phenomenon adds another dimension to the issue of communicating uncertainty with respect to predicting a cyclone's track. Adding to uncertainty, are the predicted effects of climate change on tropical cyclones. The Climate Council [30] reports that while TC are likely to become less frequent, Australia is likely to experience more intense or severe TC resulting in stronger winds and heavier rainfall. Another projection is that a greater number of TC may track further south along Australia's east and west coasts [34]. As this occurs, communities with no prior experience of TC will be exposed and highly vulnerable. Even without a change in TC frequency or intensity, growing populations in at-risk regions is increasing our exposure.

The devastation wrecked on Darwin and surrounding regions by Severe TC Tracy in 1974 influenced the shift from the crisis management, response oriented approach towards the disaster risk reduction paradigm as seen in Australia today [39,48,61]. Although in the immediate decades following Severe TC Tracy, TC disaster management centred around mitigating impacts of wind damage on the built environment [61,64]. This is in line with a historical trend, including into the IDNDR, to concentrate on the physical phenomena of the hazards themselves and the corresponding emergency response as opposed to enhancing community awareness of and preparedness for natural hazards [48,70,73].

Since then, however, the need for community education to enhance preparedness and response has been highlighted by various studies. For example, Berry and King [7] showed that households in Far North Queensland had low perceptions of personal risk and were inadequately prepared and unwilling to respond to warning messages when a threat was imminent. These responses can be attributed to a number of factors, including: a high number of new residents to the area who had little to no previous experience of tropical cyclones; residents' preference to trust their own judgements rather than advice from the emergency services; and, false perceptions that the topography (i.e. mountains, rainforest and reef) would provide sufficient protection from wind damage and storm surge[4] [7].

Consistent with household findings, low levels of understanding relating to the processes of cyclone and storm surge were found among school aged children from the same area [7]. These results were of concern, given the frequency of TC in the region (e.g. TC Winifred, 1986; TC Joy, 1990; TC Justin, 1997; TC Rona, 1999; TC Steve, 2000; TC Larry, 2006; and TC Yasi, 2011). As a direct result of this research, *'Stormwatchers'* was developed by the Bureau and James Cook University, with the aim to raise awareness and enhance protective actions among school children and their families [7]. As a 3D interactive web based game, *Stormwatchers* is still available and relevant to all children living in cyclone prone regions across Australia [16].

More rigorous education campaigns targeted at enhancing community preparedness and response to warnings have also been developed and implemented by local councils, state governments and the

[4] The increased height in sea levels as tropical cyclones make landfall are known as storm surges. Storm surges are caused by strong onshore winds and / or reduced atmospheric pressure [18].

emergency services. The success of these was highlighted during Severe TC Larry, which approached the coast as a Category 5 system before being downgraded to Category 4 as it made landfall near Innisfail in March 2006. In post-impact surveying, King et al. [59] found that the population responded positively to warnings; they were aware of the risk and were predisposed to undertake preparedness activities during the cyclone season, whether or not there was an imminent threat. As a result, there were no fatalities and very few injuries. However, King et al. [59] clarified that many respondents had previous experience of cyclone impacts which may have influenced their willingness to proactively prepare and heed warning advice.

Despite these positive results, there was a significant number of small insurance claims, indicating that more targeted community education campaigns are needed to enhance household preparedness with respect to reducing damage to outdoor items ([82]; please note, data pertains to Severe TC Larry and Yasi combined). Furthermore, there was criticism towards the communication of warning advice. Many people received conflicting information from media sources when compared to the Bureau's warnings, citing that the media were often broadcasting out-dated information [59]. Obviously, this caused some confusion and highlighted the critical need for accurate, clear, consistent and timely information, with residents calling for more regular warnings as the cyclone approached the coast.

There has, however, been many upgrades to the Bureau's Tropical Cyclone Warning system, including the implementation of the seasonal and shorter-term outlook, extended TC track map and information, satellite and radar graphical displays, and enhanced Tropical Cyclone Advice providing the Watch and Warning messaging. These upgrades have resulted from a combination of learned experience through continuous review process, research and improved capability and capacity development in systems and forecast processes, mostly linked to enhanced resourcing [14].

The TC Watch is 'issued when sustained gale force winds or damaging wind gusts associated with a tropical cyclone are expected to affect coastal communities within 48 h, but not expected within 24 h' [24]. The Bureau issues a TC Warning when 'sustained gale force winds or damaging wind gusts associated with a tropical cyclone are affecting or is expected to affect coastal and island communities within 24 h' [24]. Adding detail to the timeframes is the predicted and actual intensity of the cyclone, described in Australia as Category 1–5. This system has been in place since the 1980s following the identification of issues surrounding misinterpretations relating to definitions of low pressure system, TC or Severe TC by sustained mean wind speeds [14].

With improved online services and an increase in the use of social media, there was a marked difference between Severe TC Larry and Yasi with respect to the community's ability to access information and the amount of information available. Severe TC Yasi crossed the Far North Queensland coast near Mission Beach in February 2011 as a Category 4 system. Despite the uncertainty as to where the cyclone would make landfall, there were no fatalities but many towns experienced significant damage to homes, businesses and property. Due to the size and magnitude of this system as a large Category 5 cyclone approaching the coast, there was a huge emphasis from the emergency services and media alike to enhance community preparedness and response.

Media outlets, however, were suggesting that Severe TC Yasi would annihilate the Queensland coast, being worse than Severe TC Larry and Tracy, with the power of four Hiroshima bombs [83]. Understandably, this created great concern among those in its path as well as those watching the event unfold from a distance. Woods et al. [100] identified a sense of hopelessness and helplessness among those at-risk, citing that much of the fear and panic could have been avoided if media outlets focused on the facts to motivate people to take action rather than sensationalising worst-case scenarios. Taylor et al. [83], however, reported that people turned to community Facebook groups, such as 'Cyclone Yasi Update', which incidentally acted as a form of psychological first aid. Through such groups, people felt a sense of connectedness, as they received or gave timely and ongoing safety advice and support, with information personalised for users and reflecting the local context [8,83].

Since Yasi, the Bureau has implemented further developments, including the dissemination of hourly warnings and an increased social media presence, with Twitter being the predominant platform. Furthermore, the Bureau's TC warning information was extended to MetEYE during the 2015/16 TC season, resulting in publicly available 5-day TC track maps. This enhanced capability allows users to drill down into their area to extract more detailed localised information about expected conditions [23].

While significant improvements to observation and forecasting capability have decreased the scientific uncertainty, levels of uncertainty remain high among those vulnerable, which in turn, influences their risk perceptions and interpretations of warnings, as was evident during Severe TC Marcia. This event approached the Central Queensland coast, just north of Yeppoon in March 2015 as a Category 5 cyclone. In a post-impact survey, Bird et al. [11] found that many residents were uncertain of the fact or did not believe that a Category 4 or 5 TC could impact the area where they lived. This lack of perceived risk led to complacency, with residents and some officials believing, due to past experiences where warnings had been given but the cyclone did not impact their region, it would be another 'near miss'. As a result, the warnings were interpreted as 'overrated' and in many instances, ignored up until a few hours before Severe TC Marcia made landfall – a time when people should be sheltering in a safe location with their homes and properties well prepared. Bird et al. [11] also noted there was confusion with respect to the advice given, as residents were unaware of the difference between a TC Watch and Warning.

In addition to enhancing public understanding of their own risk in relation to specific events, TC Watch and Warning advice is also critical to the emergency services for the dissemination of relevant action advice based on alert levels. For example, recent recommendations stemming from a review of cyclone and storm tide[5] sheltering arrangements following Severe TC Marcia highlight the critical importance of timely warnings for preparing places of refuge [54]. Based on the rapidly escalating events of TC Marcia, IGEM [54] outlined the need to re-examine emergency management guidelines and plans, based on the Bureau's standard TC Watch and Warning timeframes.

The latest TC Watch and Warnings are broadcast across multiple channels, including local radio, television, social media, online and via a recorded message accessed by telephoning a 1300 no. relevant to the area. Since this information is presented in a single location, such as the Bureau's national website, BoM [14] recognises the need for national consistency. Currently, however, each region provides their own distinct information[6] in terms of alert levels and action advice based on the Bureau's suite of products.

Confusion surrounding warnings and impact messages and how they related to local circumstances is still apparent, as was evidenced with the impact of Severe TC Debbie on the Whitsunday Coast in April 2017 [43]. Furthermore, as Severe TC Debbie was a large but relatively slow-moving system that changed course a number of times, resulting in the Bureau issuing extensive Watch and Warning zones, people became complacent with their preparations, choosing not to act until the threat was imminent [43]. Again, media outlets sensationalised the impending event heightening people's fear and panic before TC Debbie made landfall. As a result of these factors (and possibly others), only a small number of respondents chose to evacuate, with people choosing to shelter in place despite the risk [75]. While IGEM [55] showed that residents received warning information from a variety of sources during

[5] A storm tide is the combined effect of storm surge and astronomical tide [16].

[6] See, for example: http://www.pfes.nt.gov.au/Emergency-Service/Public-safety-advice/Cyclones/Cyclone-action-guide.aspx, https://www.qld.gov.au/emergency/dealing-disasters/cyclone-severe-storm.html and https://www.dfes.wa.gov.au/safetyinformation/warningsystems/Pages/CycloneWarningSystem.aspx.

Severe TC Debbie, the Bureau and the Australian Broadcasting Corporation (ABC) were of critical importance. IGEM [55] recommended that further opportunities for collaboration should be explored between these two agencies and local councils with the aim to enhance warning messages. This would certainly help to address the call for the Bureau to use less formal language that is more personalised to the local context [75].

As a result of various impact assessments and community surveys, the following recommendations were made specifically related to enhancing the effectiveness of warnings to the community:

- *Analyse factors influencing community decisions to evacuate, alongside a review of communication and messaging about evacuations.*
- *Analyse the strengths and limitations of automated messaging and how this could be improved.*
- *Examine ways for greater integration of Bureau warnings with state and local emergency services messaging.*
- *Examine operationalising the use of Facebook in real-time to warn communities leading up to and during severe weather events.*
- *Provide more emphasis in warnings about severe weather impacts following landfall.*
- *Review the style of language used in warnings, and optimise web design and social media channels so that messages can be more readily accessed and understood by local communities.*
- *Revise advice to households to store more than three days of food and water given the potential for protracted isolation.*
- *Provide education to residents to ensure a battery operated radio is part of their emergency kit as mobile phones cannot be relied upon as the only means of access to warning information, particularly during extended power outages* [75, p.7].

While the Bureau has made significant progress in enhancing its TC warning capabilities, it is evident that much work is still needed to improve community preparedness and response (e.g. see [75]). Events throughout the last decades highlight the issue of complacency relating to low perceptions of risk; many of which can be related to misunderstandings of uncertainty. Complacency also stems from experience, where people base preparedness and response actions on past experiences of surviving cyclone impacts of a perceived similar magnitude event [35,59], when in actual fact, it may have been of a lower category. For example, communities impacted by recent Severe TCs (e.g. Larry, Yasi, Marcia and Debbie) may believe they have a lived experience of a Category 4 or 5 Cyclone, but in reality, Category 4 or 5 winds only occurred in specific locations. Beyond that, these events also highlight the critical link between the Bureau and emergency services with respect to impact forecasting that informs localised risk-based warnings.

4. Discussion: application of the Total Warning System Concept

Inquiries over the past decades following major catastrophic events, both in Australia and internationally have explored warnings failures where community decisions and actions in response to messages have not dramatically minimised loss of life, property and suffering. Warnings are complex; they need to convey a range of information about impending peril that ultimately supports protective action. The outcomes of the various reviews and inquiries and associated research discussed above, together with the implementation of the Sendai Framework for Disaster Risk Reduction have sent a clear message - to enable decisions that support appropriate risk mitigating actions at all levels of society (policy makers to individuals in households) there is a need for warnings to be people-centred.

Furthermore, warning messaging should focus on effective communication of risk and the inherent associated uncertainty, in addition to the likely impact. Throughout the case studies lack of risk perception is persistently linked to inaction or inadequate action in response to warnings messages. For many community members, this is not apathy, nor is it ignorance; it is an active decision that the described risk is not an issue for them and therefore an often-considered decision not to take appropriate protective action. Perception by the public that previous 'near-misses' were actually false alarms can erode the public's confidence in warnings messages, creating a degree of warning fatigue that can undermine the veracity of future warnings [63]. Research described above shows that a biased perception of risk can result from lack of experience with the hazard in relation to their individual circumstances. Vulnerability and exposure to hazard impact is increasing, as more people and infrastructure are located in hazard prone areas such as floodplains and along the fire-prone rural-urban fringe. It is also argued that the impacts of climate change will further expose many communities to unfamiliar hazards with the changing of hazard regimes, such as the southward migrating Severe TC's [56].

Insufficient action has also been attributed to information in warnings messages that focuses on the hazard elements and recommended defensive or response actions. As stated earlier, warnings that describe what the weather will be rather than what the weather will do. Typically, the information that recommends action has not been designed with a good understanding of what *motivates* action, due primarily to limitations in knowledge and research. To communicate risk that prompts action it is important that the information is understood, believed, trusted and promotes a sense of self-efficacy; the language used should not be so dire as to immobilise people through a sense of fear, panic or hopelessness.

Based on developments in international strategies, national policies, the successful application of the Total Flood Warning System for flood related hazards, the social research and the outcomes of inquiries following disasters, an adapted revised version of the Total Warning System concept (Fig. 5) has been developed. This approach emphasises and reinforces the 'human' (as opposed to the system/technical) elements of the concept.

Importantly, the revised Total Warning System concept aims to strengthen the components of dissemination, communication and adoption of protective actions by considering how they are influenced by a warning recipient's comprehension, trust and personalisation of warning information. Post-incident research has shown that people regularly report not receiving adequate warning, despite an apparent awareness of the hazardous event via multiple communication channels (e.g. [28]). Therefore, in the successful dissemination of warnings, it cannot be assumed that warnings will be recognised as such and understood and trusted by recipients, or that the risk to an individual or household is understood, believed and personalised simply because they have received a warning. These are crucial elements in the decision making process for effective response to emergency situations and need to be considered with the development of future impact forecasting and risk-based warning systems for Australia.

In order to shift to impact forecasting and risk-based warning services, incorporation of risk assessment information that goes beyond current practices of natural hazard risk modelling, needs to occur at the *forecasting* stage (see Fig. 5). While Manual 21 frequently talks about the need to include impact and risk information for flood warnings [5], risk assessments do not currently integrate specific (spatial and temporal) hazard forecasts with exposure and vulnerability data at the community level for any hazard warnings within Australia [77]. From here, translating forecast information and constructing warning messages (the *message communication* stage) to include relevant exposure and vulnerability intelligence, tailored to meet community expectations about location, likelihood, and potential impacts, while also using accessible language, is required. Inquiry findings, notably those relating to bushfires, found individuals were only receptive to information when a threat was imminent with further complexities around warning compliance created by warning fatigue. This provides crucial information for warning and emergency response agencies as to what information (uncertainty, impacts and risk, action advice) to include in

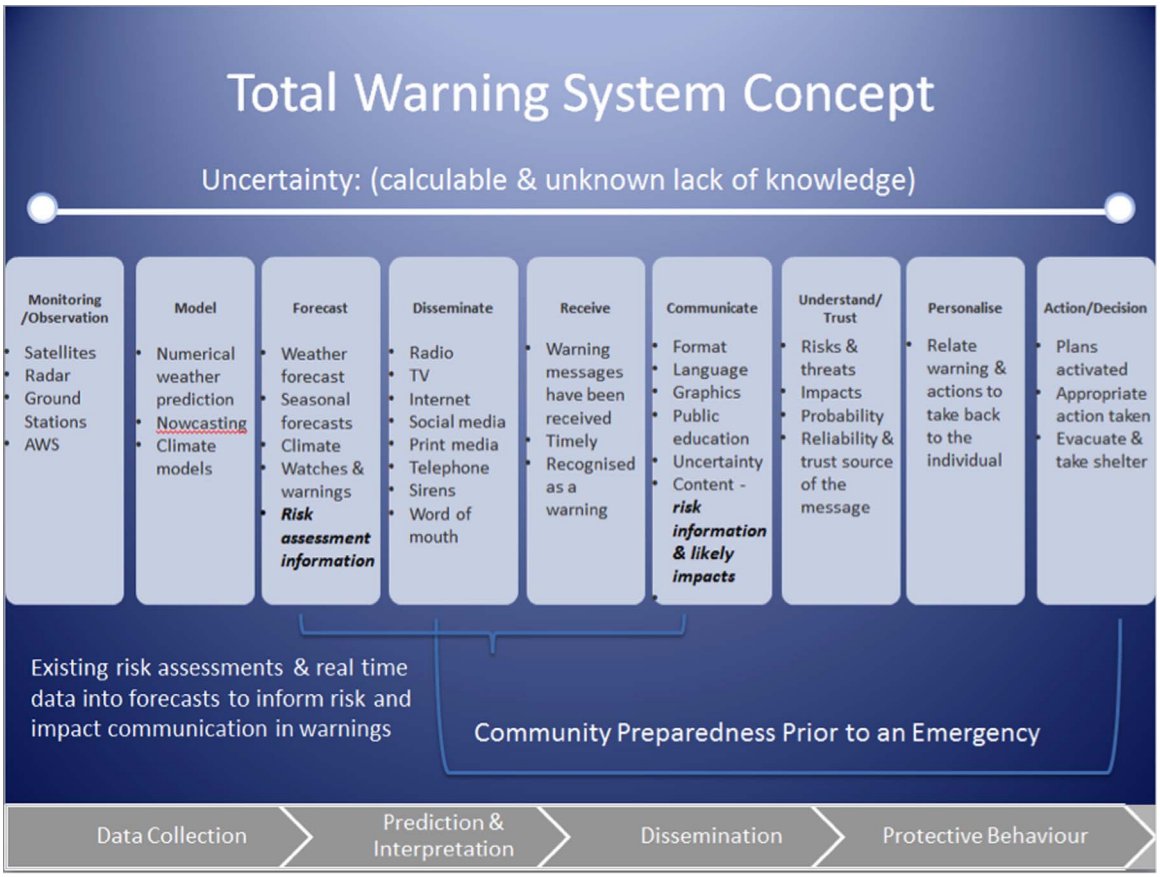

Fig. 5. The Total Warning System concept demonstrates the shift to people-centred warning systems in Australia. This graphic shows at which point in the warning system, risk information would be incorporated into the systems to then be communicated as potential impacts through the warnings, acknowledging the uncertainty inherent throughout. The Review and other multi-hazard early warning systems models suggest that warnings will only be truly effective when community preparedness has been undertaken prior to emergency events. Figure constructed by first author of this paper. Information derived from Manual 21 [5] and the Review [40].

future warning products [63,67,96], as well as issues to target in pre-season education and preparedness programs.

The role for community education and preparedness is highlighted in the Review asserting that the success of '*warnings during an emergency is highly dependent upon prior efforts to build community preparedness and resilience*' [40, p.5]. While this key issue is not new, the review following the 2010–2011 Victorian Floods highlighted additional components that require further emphasis through the Total Warning System concept that align with preparedness activities, e.g. understanding flood risk, emergency management planning and community flood education [38]. Improving preparedness and education programs will require a better understanding by warning agencies of communities and how to address their needs. Factors that should be considered for emergency planning, community preparedness and education, warning message construction and communication and response include land-use, potential social vulnerabilities and types of populations (e.g. aging, transient) of at-risk communities.

In addition, warning agencies should have an appreciation about the importance of social capital among communities and the positive role it can play in all phases of the risk management process including preparedness, warning and response [37]. Social capital is often described as the invisible threads that hold community networks together. Family groups usually help each other, but groups of friends and neighbours extend these networks. The OECD (2001 in [80, p.41]) defines social capital as.: '*networks, together with shared norms, values and understandings which facilitate co-operation within or among groups*'. Research has shown that communities with high levels of social capital are cohesive and this can result in residents banding together to warn and protect each other and assist each other during responses such as evacuations [37]. Unlike physical capital, social capital is not depleted when it is used, rather it is enhanced. If social capital is low and warning messages aren't passed on, risk-taking behaviour may result, e.g. people undertaking dangerous evacuations or ignoring warnings and driving through floodwater. Programs like the Community Fire Units in New South Wales and the Australian Capital Territory are excellent examples of emergency services supporting local residents in an effort to enhance preparedness and response to bushfire threats while building social capital [10,50].

Uncertainty is inherent in every element of the Total Warning System. Studies indicate that decision making is improved through provision of uncertainty in forecasts and warnings, with the most effective responses resulting when communication of uncertainty is paired with recommended actions [58]. Broadening the understanding about the 'calculability of uncertainty' beyond probabilistic and assessable terms, 'social scientists argue that uncertainty is always connected to an unknown lack of knowledge' [60, p.292]. Uncertainty can be present in the physical aspects of the hazard. It also needs to be recognised and addressed within forecast formats [46] language around forecasts and recommended actions, the source and channel of messages, interpretation of communication methods (text based, graphical, numerical prediction) and, personalisation of information e.g., is the information localised and frequent enough to make an effective decision.

The presentation of information influences how it will be construed. Hudson-Doyle et al. [52] showed that the format of probability statements (i.e. numerical or verbal) biases people's understanding of probability and affects their choices of appropriate action. Verbal statements of probability convey additional information that frames the

outcome in either a positive or negative light, e.g. 70% chance of success compared to 30% chance of failure, thus further influencing whether or not people adopt protective strategies [52]. Interestingly, McClure and Sibley [65] discovered that people were more likely to adopt protective measures when information was framed in a negative light.

The delivery of a Total Warning System is clearly the collective responsibility of a partnership that includes the Bureau, emergency services, government agencies across all levels, media, local community organisations, educators, researchers, private sector providers and the public. The success of the system will depend on the strengths of these partnerships and the interplay of roles and responsibilities [40]. The roles and responsibilities of emergency services and local government within the context of an impact forecasting and risk-based warning system are centred on the interpretation and dissemination of warnings about the likely impacts of a hazard to the Australian community.

5. Conclusion

The evidence arising from a range of reports and inquiries relating to multiple extreme hazard events, is consistent and unanimous. When confronted with the impact of a major hazard event community safety and resilience is dependent on an effective warnings system that is specifically and directly relevant to those at risk, i.e., one that is people-centred. Ideally it contains information and detail relating to the hazard together with enough information about likely impact for those in harms way to make risk-informed decisions about taking defensive actions; some advice on appropriate actions; and, sources of further information.

International literature, Australian warnings policy documents and social research considering the effectiveness of warnings, as discussed through the various case studies that focussed on flood, fire and tropical cyclone hazards, clearly indicate the need to move towards a people-centred, impact forecasting and risk-based warnings system, within a Total Warnings System concept. This has been acknowledged and agreed by all partners with a role in community warnings. The shift towards this and away from hazard and action focussed warnings messaging is an evolutionary and, in the Australian context, staged process. It is understood that to successfully develop and implement such a system is a major undertaking. All the components discussed above, together with: agreed and well defined roles and responsibilities among all agencies and sector partners; established warnings and emergency management legislation and arrangements; strong partnerships (often newly-formed in the warnings context); consistency of warning services; and, inclusion of risk, impact and uncertainty information, must present and integrated in a Total Warnings System.

Under the direction of the ANZEMC, and with the support of all Australian governments, policy frameworks, organisational processes and special arrangements are currently being established through cross-jurisdictional, multi-agency task-forces and working groups, and formalised agreements. Projects that will deliver an enhanced understanding and description of vulnerability and risk across the Australian social landscape, and improve the ability to share and merge hazard and risk-related information in the production of warnings are being scoped and supported by a range of Commonwealth and State / Territory agencies.

Acknowledgements

Deanne Bird has been supported by the Nordic Centre of Excellence for Resilience and Societal Security – NORDRESS, which is funded by the Nordic Societal Security Programme.

References

[1] AEMC, Australia's revised arrangements for bushfire advice and alerts – 2009/2010 Fire Season. Version 1.1 - 7 October 2009, ⟨https://www.fire.tas.gov.au/userfiles/tonym/file/Revised_Arrangements_for___Report-_Version_1_1_FINAL.pdf⟩, (Accessed 27 January 2018), 2009.
[2] AEMI, Sendai framework for disaster risk reduction 2015–2030, Aust. J. Emerg. Manag. 30 (2015) 9–10.
[3] AFAC, Council Resolution, October 2014, Australian Fire and Emergency Services Authorities Council, Melbourne, 2014.
[4] AFAC, National Fire Danger Rating System, ⟨https://www.afac.com.au/initiative/nfdrs⟩, (Accessed 27 January 2018), 2017.
[5] AIDR, Manual 21, Flood Warnings, Australian Institute for Disaster Resilience. ⟨https://www.aidr.org.au/media/1445/manual-21-flood-warning.pdf⟩, (Accessed 16 May 2017), 2009.
[6] Attorney-General's Department, Australia's Emergency Warning Arrangements, Attorney-General's Department. ⟨https://www.ag.gov.au/Publications/Documents/AustraliasEmergencyWarningArrangements/Australias-Emergency-Warning-Arrangements.pdf⟩, (Accessed 16 May 2017), 2013.
[7] L. Berry, D. King, Tropical cyclone awareness and education issues for far north Queensland school students storm Watchers - a cyclone awareness education package for upper primary school children, Aust. J. Emerg. Manag. Spring (1998) 25–30.
[8] D. Bird, M. Ling, K. Haynes, Flooding Facebook – the use of social media during the Queensland and Victorian floods, Aust. J. Emerg. Manag. 27 (2012) 27–33.
[9] D. Bird, D. King, K. Haynes, P. Box, T. Okada, K. Nairn, Impact of the 2010/11 Floods and the Factors that Inhibit and Enable Household Adaptation Strategies, National Climate Change Adaptation Research Facility, Gold Coast, Australia, 2013.
[10] D. Bird, R. van den Honert, J. O'Brien, A., K., H. Gissing, Evaluation of the Community Fire Unit program in the ACT. Report prepared for ACT Fire & Rescue, Risk Frontiers, Melbourne, 2016.
[11] D. Bird, S. Panchuk, K. Ronan, L. Anderson-Berry, C. Hanley, S. Canterford, I. Mannix, B. Gunn, Severe Tropical Cyclone Marcia: an examination of information and warnings broadcasted to inform mitigation and community preparedness, AFAC, Brisbane, 2016.
[12] R. Blanchi, J. Leonard, K. Haynes, K. Opie, M. James, F.Dd Oliveira, Environmental circumstances surrounding bushfire fatalities in Australia 1901–2011, Environ. Sci. Policy 37 (2014) 192–203.
[13] BoM. Tropical Cyclone Rewa, ⟨http://www.bom.gov.au/cyclone/history/rewa.shtml⟩, (Accessed 21 July 2017).
[14] BoM, Tropical Cyclone Warning Services Strategic Plan, Australian Government, 2009, p. 22.
[15] BoM. National Arrangements for Flood Forecasting and Warning, ⟨http://www.bom.gov.au/water/floods/document/National-Arrangements.pdf⟩, (Accessed 20 July 2017).
[16] BoM. Stormwatchers Game, ⟨http://www.bom.gov.au/storm_watchers_game/⟩, (Accessed 29 June 2017).
[17] BoM. Frequently Asked Questions: Tropical Cyclone FAQs, Definitions, ⟨http://www.bom.gov.au/cyclone/faq/index.shtml⟩ - definitions (Accessed 29 June 2017).
[18] BoM. Storm Surge Preparedness and Safety, ⟨http://www.bom.gov.au/cyclone/about/stormsurge.shtml⟩, (Accessed 29 June 2017).
[19] BoM. Understanding tropical cyclone categories – video, ⟨http://www.bom.gov.au/cyclone/about/⟩, (Accessed 27 July 2017).
[20] BoM. Maximum Fire Danger Index Maps, ⟨http://www.bom.gov.au/vic/forecasts/fire-map.shtml⟩, (Accessed 3 August 2017).
[21] BoM. Southern Hemisphere Tropical Cyclone Data Portal, ⟨http://www.bom.gov.au/cyclone/history/tracks/index.shtml⟩, (Accessed 21 July 2017).
[22] BoM. About Tropical Cyclones, ⟨http://www.bom.gov.au/cyclone/about/⟩, (Accessed 27 July 2017).
[23] BoM. Blog Ten Tips for a More Detailed Weather Forecast, ⟨http://media.bom.gov.au/social/?Ref=ftr⟩, (Accessed 27 July 2017).
[24] BoM. Tropical Cyclone Warning Services, ⟨http://www.bom.gov.au/cyclone/about/warnings/⟩, (Accessed 29 June 2017).
[25] BoM. Flood Warning Services, ⟨http://www.bom.gov.au/water/floods/floodWarningServices.shtml⟩, (Accessed 31 January 2018).
[26] H.J. Boon, Perceptions of climate change risk in four disaster-impacted rural Australian towns, Reg. Environ. Change (2014) 1–13.
[27] A. Bruns, J. Burgess, K. Crawford, F. Shaw, #qldfloods and @QPSMedia: Crisis Communication on Twitter in the 2011 South East Queensland Floods, ARC Centre of Excellence for Creative Industries and Innovation, Brisbane, 2012.
[28] S. Canterford, V. Juskevics, M. Middelmann-Fernandes, M. Wehner, W. Oh, Household experiences of flooding in Brisbane and Ipswich, Queensland: Results of Geoscience Australia surveys following flooding in South East Queensland in 2011 and 2013. Record 2016/30. Geoscience Australia, Canberra, 2016.
[29] H. Clarke, C. Lucas, P. Smith, Changes in Australian fire weather between 1973 and 2010, Int. J. Climatol. 33 (2013) 931–944.
[30] Climate Council, Fact Sheet: Tropical Cyclones and Climate Change, ⟨https://www.climatecouncil.org.au/fact-sheet-tropical-cyclones-and-climate-change⟩, (Accessed 27 July 2017), 2017.
[31] L. Coates, K. Haynes, J. O'Brien, J. McAneney, F. Dimer de Oliveira, Exploring 167 years of vulnerability: an examination of extreme heat events in Australia 1844–2010, Environ. Sci. Policy 42 (2014) 33–44.
[32] N. Comrie, State Government Victoria (Ed.), Review of the 2010-11 Flood Warnings and Response, State Government Victoria, Melbourne, 2011.
[33] R.P. Crompton, K.J. McAneney, K. Chen, R.A. Pielke, K. Haynes, Influence of location, population, and climate on building damage and fatalities due to Australian Bushfire: 1925–2009, Weather Clim. Soc. 2 (2010) 300–310.
[34] CSIRO, BoM, Climate Change in Australia – Technical Report, CSIRO and Bureau of Meteorology, Melbourne, 2015, p. 216.

[35] S. Cullinan, Lessons from cyclone Debbie: how important is preparation? Aust. J. Emerg. Manag. 32 (2017) 16–17.
[36] E. Du, S. Rivera, X. Cai, L. Myers, A. Ernest, B. Minsker, Impacts of human behavioral heterogeneity on the benefits of probabilistic flood warnings: an agent-based modeling framework, JAWRA J. Am. Water Resour. Assoc. 53 (2017) 316–332.
[37] N. Dufty, The importance of connected communities to flood resilience, in: Proceedings of the 8th Victorian Flood Conference Melbourne, Australia, 2013.
[38] N. Dufty, Developing Total Flood Warning Systems, This document is available as a Kindle e-book 〈https://www.amazon.com/Developing-Total-FloodWarning-Systems-ebook/dp/B0769D62BN/ref=sr_1_2?Ie=UTF8&qid=1512441992&sr=8-2&keywords=neil+dufty〉, (Accessed 7 December 2017), 2017.
[39] A. Dwyer, Cyclone Tracy and Whitlam's 'new' federalism: implications for the management of natural disasters in Australia, Aust. J. Emerg. Manag. 21 (2006) 41–46.
[40] EMV. National Review of Warnings and Information: Final Report, Emergency Management Victoria, Victorian Government. 〈http://files.em.vic.gov.au/EMV-web/National-Review-of-Warnings-and-Information-Final-Report-ANZEMC-Endorsed.pdf〉, (Accessed 27 July 2017).
[41] A. Gissing, C. Keys, S. Opper, Towards resilience against flood risks, Aust. J. Emerg. Manag. 25 (2010) 41–47.
[42] A. Gissing, K. Haynes, L. Coates, C. Keys, Motorist behaviour during the 2015 Shoalhaven floods, Aust. J. Emerg. Manag. 31 (2016) 25–30.
[43] Y. Gurtner, A. Vachette, Tropical Cyclone Debbie, Whitsunday Coast, QLD, Australia. 5–8 April 2017. Community Post Impact Assessment – Rapid Appraisal, James Cook University, Townsville, 2017, p. 30.
[44] P. Hall, Early warning systems: reframing the discussion, Aust. J. Emerg. Manag. 22 (2007) 32–36.
[45] J. Handmer, Are flood warnings Futile? Risk communication in emergencies, Australas. J. Disaster Trauma Stud. 2000-2 (2000).
[46] J. Handmer, B. Proudley, Communicating uncertainty via probabilities: the case of weather forecasts, Environ. Hazards 7 (2007) 79–87.
[47] K. Haynes, J. Handmer, J. McAneney, A. Tibbits, L. Coates, Australian bushfire fatalities 1900–2008: exploring trends in relation to the 'prepare, stay and defend or leave early' policy, Environ. Sci. Policy 13 (2010) 185–194.
[48] K. Haynes, D.K. Bird, D. Carson, S. Larkin, M. Mason, Adaptation Lessons from Cyclone Tracy Part II: institutional response and Indigenous experience of Cyclone Tracy. Report for the National Climate Change Adaptation Research Facility Gold Coast, Australia, 2011, p. 79.
[49] K. Haynes, D. Bird, J. McAneney, Mitigate damage risk from bush fires, Nature 503 (2013) (469-469).
[50] K. Haynes, D. Bird, Investigating the activation of Community Fire Units in the Blue Mountains during the October 2013 bushfires, Bushfire and Natural Hazards Cooperative Research Centre, East Melbourne, 2014, p. 104.
[51] K. Haynes, L. Coates, R. van den Honert, A. Gissing, D. Bird, F. Dimer de Oliveira, R. D'Arcy, C. Smith, D. Radford, Exploring the circumstances surrounding flood fatalities in Australia—1900–2015 and the implications for policy and practice, Environ. Sci. Policy 76 (2017) 165–176.
[52] E.E. Hudson-Doyle, J. McClure, D.M. Johnston, D. Paton, Communicating likelihoods and probabilities in forecasts of volcanic eruptions, J. Volcanol. Geotherm. Res. 272 (2014) 1–15.
[53] L. Hughes, J. Fenwick, The Burning Issue: Climate Change and the Australian Bushfire Threat, Climate Council of Australia Ltd. 〈https://www.climatecouncil.org.au/uploads/df9df4b05bc1673ace5142c3445149a4.pdf〉, (Accessed 16 August 2017), 2015.
[54] IGEM, Review of cyclone and storm tide sheltering arrangements. Report 3: 2014-15, The State of Queensland, Office of the Inspector-General Emergency Management. 〈https://www.igem.qld.gov.au/reports-and-publications/documents/Review-of-Cyclone-and-Storm-Tide-Sheltering-Arrangements.pdf〉, (Accessed 30 June 2017), 2015.
[55] IGEM, The Cyclone Debbie Review: Lessons for Delivering Value and Confidence through Trust and Empowerment. Report 1: 2017–18, Office of the Inspector-General Emergency Management, Brisbane, 2017, p. 135.
[56] IPCC, IPCC Working Group I Fifth Assessment Report. Intergovernmental Panel on Climate Change, Geneva, 2013.
[57] R. Jones, In search of the 'prepared community': the way ahead for Australia? Aust. J. Emerg. Manag. 28 (2013) 17–21.
[58] S.L. Joslyn, J.E. LeClerc, Uncertainty Forecasts Improve Weather-Related Decisions and Attenuate the Effects of Forecast Error, J. Exp. Psychol.: Appl. 18 (2012) 126–140.
[59] D. King, D. Goudie, D. Dominey-Howes, Cyclone knowledge and household preparation – some insights from cyclone Larry, Aust. J. Emerg. Manag. 21 (2006) 52–59.
[60] T. Kox, L. Gerhold, U. Ulbrich, Perception and use of uncertainty in severe weather warnings by emergency services in Germany, Atmos. Res. 158 (2015) 292–301.
[61] G. Li, (Mal)adapting to tropical cyclone risk: the case of 'Tempestuous Tracy', Aust. J. Emerg. Manag. 24 (2009) 44–51.
[62] M.K. Lindell, R.W. Perry, The protective action decision model: theoretical modifications and additional evidence, Risk Anal. 32 (2012) 616–632.
[63] B. Mackie, Warning Fatigue: Insights from the Australian Bushfire Context (Doctoral Thesis), University of Canterbury, 2014 〈https://ir.canterbury.ac.nz/handle/10092/9029〉 (Accessed 13 November 2017).
[64] M. Mason, K. Haynes, Cyclone Tracy Part 1: the Engineering Response, Report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia, 2010.
[65] J. McClure, C.G. Sibley, Framing effects on disaster preparation: is negative framing more effective? Aust. J. Disaster Trauma Stud. (2011) (2011-1).
[66] J. McLennan, G. Elliott, M. Omodei, Householder decision-making under imminent wildfire threat: stay and defend or leave? Int. J. Wildland Fire 21 (2012) 915–925.
[67] J. McLennan, G. Elliott, M. Omodei, J. Whittaker, Householders' safety-related decisions, plans, actions and outcomes during the 7 February 2009 Victorian (Australia) wildfires, Fire Saf. J. 61 (2013) 175–184.
[68] J. McLennan, D. Paton, R. Beatson, Psychological differences between south-eastern Australian householders' who intend to leave if threatened by a wildfire and those who intend to stay and defend, Int. J. Disaster Risk Reduct. 11 (2015) 35–46.
[69] J. McLennan, D. Paton, L. Wright, At-risk householders' responses to potential and actual bushfire threat: an analysis of findings from seven Australian post-bushfire interview studies 2009–2014, Int. J. Disaster Risk Reduct. 12 (2015) 319–327.
[70] D. Mileti, Disasters by Design: a Reassessment of Natural Hazards in the United States, The National Academies Press, Washington, DC, 1999, p. 371.
[71] D.S. Mileti, J.H. Sorensen, Communication of Emergency Public Warnings: a Social Science Perspective and state-of-the-art assessment, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, TN, 1990, p. 128.
[72] D.S. Mileti, J.H. Sorensen, A Guide to Public Alerts and Warnings for Dam and Levee Emergencies. U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center, Davis, CA, 2015, p. 24.
[73] S.A. Morrissey, J.P. Reser, Evaluating the effectiveness of psychological preparedness advice in community cyclone preparedness materials, Aust. J. Emerg. Manag. 18 (2003) 46–61.
[74] D.J. Parker, S.J. Priest, S.M. Tapsell, Understanding and enhancing the public's behavioural response to flood warning information, Meteorol. Appl. 16 (2009) 103–114.
[75] QTCCC, Tropical Cyclone Debbie Forum Summary Report, Queensland Tropical Cyclone Consultative Committee, Brisbane, 2017, p. 20.
[76] Queensland Flood Commission, Queensland Floods Commission of Inquiry. Final Report, Queensland Government, Brisbane, 2012, p. 654.
[77] H. Richter. Forecasting impact for severe weather, Bushfire and Natural Hazards CRC. 〈http://www.bnhcrc.com.au/research/hazard-resilience/3398〉, (Accessed 31 January 2018).
[78] R.W. Rogers, A protection motivation theory of fear appeals and attitude Change1, J. Psychol. 91 (1975) 93–114.
[79] W.A. Rogers, N. Lamson, G.K. Rousseau, Warning Research: an Integrative Perspective, Hum. Factors 42 (2000) 102–139.
[80] K. Scrivens, C. Smith, Four Interpretations of Social Capital: an Agenda for Measurement, OECD Statistics Working Papers 2013/06, OECD Publishing, Paris, 2013, p. 70.
[81] L. Short, C. Shackleton, D. Sparkes, A new national fire danger rating system, in: Proceedings of the AFAC - Fire and Emergency Management Conference, Sydney, 2017.
[82] D. Smith, D. Henderson, Report for: suncorp Group Limited. Insurance Claims Data Analysis for Cyclones Yasi and Larry, Cyclone Testing Station, College of Science, Technology and Engineering, James Cook University, Townsville, Queensland, 2015, p. 53.
[83] M. Taylor, G. Wells, G. Howell, B. Raphael, The role of social media as psychological first aid as a support to community resilience building : a Facebook study from 'Cyclone Yasi Update, Aust. J. Emerg. Manag. 27 (2012) 20–26.
[84] B. Teague, R. McLeod, S. Pascoe, Fire preparation, response and recovery. Final Report, 2 2009 Victorian Bushfires Royal Commission, Parliament of Victoria, 2010.
[85] B. Teague, R. McLeod, S. Pascoe, 2009 Victorian bushfires Royal Commission. Final report. summary, Parliam. Vic. (2010) 42.
[86] A. Tibbits, J. Whittaker, Stay and defend or leave early: policy problems and experiences during the 2003 Victorian bushfires, Environ. Hazards 7 (2007) 283–290.
[87] V. Tippet, D. Greer, A. Mehta, S. Christensen, B. Duncan, A. Stickley, P. Dootson, Building resilient communities: effective multi-channel communication in disasters: annual project report 2015–2016, Bushfire and Natural Hazards CRC, Melbourne, 2016, p. 34.
[88] M. Tofa, K. Haynes, A. Avci, J. van Leeuwen, K. Roche, L. Coates, A. Gissing, Exploring the Experiences of Those Who Shelter in Place During Severe Flooding. Macquarie University and Bushfire Natural Hazard Cooperative Research Centre, In press.
[89] UNISDR, Hyogo Framework for Action 2005–2015: building the Resilience of Nations and Communities to Disasters, United Nations International Strategy for Disaster Reduction, Geneva, 2005, p. 24.
[90] UNISDR, Sendai Framework for Disaster Risk Reduction 2015 − 2030, The United Nations Office for Disaster Risk Reduction, Geneva, 2015, p. 37.
[91] R. van den Honert, L. Coates, K. Haynes, R. Crompton, Estimating the Impacts of Natural Hazards on Fatalities and Building Losses, in: Proceedings of the Research Forum at the Bushfire and Natural Hazard CRC & AFAC conference. Bushfire and Natural Hazard CRC & AFAC, Wellington, 2014.
[92] VICSES, News, CFA and SES join forces for forum, 〈https://www.ses.vic.gov.au/-/cfa-and-ses-join-forces-for-forum〉, (Accessed 31 January 2018), 2015.
[93] D. Webber, A. Gissing, N. Dufty, D. Bird, Community participation in emergency planning: NSW state Emergency service case study, Aust. J. Emerg. Manag. 32 (2017) 28–34.
[94] C. Wenger, K. Hussey, J. Pittock, Living with floods: key lessons from Australia and abroad, National Climate Change Adaptation Research Facility, Gold Coast, 2013, p. 267.
[95] J. Whittaker, J. Handmer, Community bushfire safety: a review of post-black Saturday research, Aust. J. Emerg. Manag. 25 (2010) 7–13.
[96] J. Whittaker, K. Haynes, J. Handmer, J. McLennan, Community safety during the 2009 Australian 'Black Saturday' bushfires: an analysis of household preparedness and response, Int. J. Wildland Fire 22 (2013) 841–849.
[97] J. Whittaker, R. Blanchi, K. Haynes, J. Leonard, K. Opie, Experiences of sheltering

during the Black Saturday bushfires: implications for policy and research, Int. J. Disaster Risk Reduct. 23 (2017) 119–127.
[98] WMO, World Meteorological Organisation Guidelines on Multi-hazard Impact-based Forecast and Warning Services 〈https://www.wmo.int/pages/prog/www/DPFS/Meetings/ET-OWFPS_Montreal2016/documents/WMOGuidelinesonMulti-hazardImpact-basedForecastandWarningServices.pdf〉 (Accessed 27 July 2017), 2015.
[99] WMO. Multi-Hazard Early Warning Systems (MHEWS), 〈http://www.wmo.int/pages/prog/drr/projects/Thematic/MHEWS/MHEWS_en.html〉, (Accessed 27 July 2017).
[100] C. Woods, C. West, P. Buettner, K. Usher, "Out of our control": living through Cyclone Yasi, Int. J. Qual. Stud. Health Well-being 9 (2014) 19821.