HOW AND WHY WE NEED TO MEASURE COMMUNITY RESILIENCE TO FLOOD, BUSHFIRE AND CYCLONE DISASTERS

Deanne K. Bird, Rob van den Honert, James O'Brien

Risk Frontiers, Department of Environmental Science, Macquarie University NSW

Abstract

A national framework has been developed to measure community resilience to disaster. The purpose of this framework is to identify the effectiveness of mitigation options in terms of reducing risk or building community resilience to disaster events such as flood, bushfire and cyclone. It is important to note, however, that resilience does not just change due to the implementation of mitigation measures. There are a multitude of factors that enhance or inhibit resilience including hazard experience, community connectedness and emergency management capacity. In the context of this project, "community resilience to disaster" is defined as a measure combining: relative exposure, social vulnerability and the community's capacity. Within this scope, relative exposure is defined as a measure of the magnitude of the impact and spatial extent of the event relative to the community as a whole. Social vulnerability looks at the exposed population's profile in terms of underlying social conditions that may make them more vulnerable to disaster, e.g. age, income and education. Community capacity is identified as the exposed population's ability to prepare, respond, recover and adapt to disaster risk and includes various factors such as social cohesion, access to a motor vehicle, community prosperity and diversity of employment base. A pilot investigation was undertaken to test the framework in three case study locations: Maribyrnong, Victoria; Kalamunda, Western Australia; and, Townsville, Queensland focusing on their resilience to flood, bushfire and cyclone, respectively. Within this paper, we focus our discussion on the appropriateness of the framework to measure community resilience to flood with respect to the other two perils and how it can aid governments in identifying where to focus community engagement, consultation and action[i]. We also consider the potential for including resilience indicators that are unique to rapid onset events, such as flood.

What did we do and why?

Building or enhancing community resilience has become a fundamental component of disaster risk reduction efforts around the world (Prior and Hagmann, 2014). In Australia, governments and others are advised through the National Strategy for Disaster Resilience to work collectively to incorporate the principle of disaster resilience (COAG, 2011). This focus, which calls for an "*integrated, whole-of-nation effort encompassing enhanced partnerships, shared responsibility, a better understanding of the risk environment and disaster impacts, and an adaptive and empowered* *community that acts on this understanding*" (COAG, 2011; p.3), takes emergency management away from the traditional practice of a paternalistic reactive stance to a proactive one that includes preparedness planning, community engagement and capacity building. By focusing more on action-based resilience building, the Council of Australian Governments (COAG) hopes that governments and agencies gain a better understanding of "*the diversity, needs, strengths and vulnerabilities within communities*" (COAG, 2011; p.2).

While Australia's National Strategy for Disaster Resilience sets out clear goals regarding resilience, there has been a lack of guidance on what is meant by resilience and how it can and should be measured. Various research projects have therefore been commissioned to investigate the meaning of resilience and possible measurement options. For example, the Torrens Resilience Institute developed a tool that a community can use to measure their resilience in relation to a major disaster or emergency (Arbon et al., 2012). The University of New England are in the process of developing an 'Australian Natural Disaster Resilience Index' to assess the current state of disaster resilience in Australian communities.

The research presented here builds from these projects, the literature and with input from key stakeholders, including officials from the Attorney-General's Department, Risk Assessment, Measurement and Mitigation Sub-Committee (RAMMS) members, AECOM and emergency management and government officials in Queensland, Victoria and Western Australia. Essentially, their input was critical, as the national framework was developed for their use in measuring community resilience to disaster across any Local Government Area (LGA) in Australia.

As Alexander (2013) argues, if the concept of resilience is to be used as an operational tool from which emergency management strategies are developed, it must be *explicitly defined* for the particular circumstance in which it is applied. Therefore, in order to quantify resilience, the type of natural hazard together with its magnitude must first be identified. With this in mind, three case study locations were engaged in a pilot study to develop and test the framework against three hazard environments: bushfire in Kalamunda, Western Australia, flood in Maribyrnong, Victoria and tropical cyclone in Townsville, Queensland.

Kalamunda, Western Australia

The Shire of Kalamunda is highly exposed to bushfire with extensive bushland areas within and adjacent to the municipality. The fire season typically runs from November through to April (DFES, 2015a). The Department of Fire and Emergency Services (DFES) is the lead agency for bushfire and provides recommendations to prepare, act and survive (DFES, 2014). Locally, the Kalamunda volunteer Bushfire Brigade, which is administered and trained by the local council and supported by DFES, works in fire prevention, risk management, fire suppression and fire safety education (DFES, 2015b). At the grassroots level, Bushfire Ready groups, consisting of local volunteers through a community action program, work together to encourage and assist residents to prepare for and respond to bushfire hazards (Kalamunda Volunteer Fire & Rescue Service, 2014). The Department of Parks and Wildlife (DPAW) also plays a role in relation to bushfire, dealing with the management of fuel loads and bushfire response in forests, parks and nature reserves, in addition to researching fire behaviour and its impacts on the environment (DPAW, no date).

Three officials working for / associated with Kalamunda Council were involved in the research, including representatives from DFES and DPAW. This involved multiple face-to-face, telephone and email discussions.

Maribyrnong, Victoria

The municipality of Maribyrnong is exposed to riverine floods, with threats resulting in the evacuation of certain households (Maribyrnong City Council, 2014a, Melbourne Water, 2013). Due to the increase in population and land use changes across the municipality, the risk of flood has increased, with approximately 400 properties vulnerable to 1-in-100 year flood events (VICSES, n.d.). As such, the Council, under the Municipal Emergency Management Plan, has developed prevention, mitigation, preparedness, response and recovery strategies so as to provide communities with the support needed to deal with the perils that threaten various parts of the city (Maribyrnong City Council, 2014b). External agencies, including Melbourne Water and the Victorian State Emergency Service (VICSES), have supported these efforts.

Over the period of the study, four council representatives provided expert knowledge and input. This involved multiple face-to-face and telephone discussions.

Townsville, Queensland

Located on the north coast of Queensland, Townsville is exposed to tropical cyclones, storm surges, flooding and bushfires. The most recent near-misses include: Severe Tropical Cyclone Yasi in 2011, which the BoM (2015a) reports crossed the coast north of Townsville at Mission Beach as a Category 5 system; and, Tropical Cyclone Larry in 2006, which also crossed the coast north of Townsville near Innisfail as a severe system (BoM, 2015b). Hence, the Townsville City Council is committed to educating residents about the risks that they may face within their communities and provides plans for safe evacuation and preparedness checklists (Townsville City Council, 2010).

Officials from Townsville City Council came from diverse sectors, including health, education and defence, alongside Queensland Fire and Emergency Services, Queensland Police Service, James Cook University and council officials in sustainability, finance, planning and emergency management. Discussions were held via face-to-face meetings, telephone conversations, workshops and a symposium. In total, more than 18 officials from Townsville contributed knowledge to the project. Their involvement was far greater than the other jurisdictions because they had been actively looking at their resilience to disaster as part of the nomination process for the Rockefeller Foundation 100 Resilient Cities program.

What does the framework look like?

According to the National Strategy for Disaster Resilience (COAG, 2011; p. iii): *"A disaster resilient community is one that works together to understand and manage the risks that it confronts."* This definition of resilience contains the notion of *risk* associated with a natural hazard, and the community's *capacity to work collectively* to prepare for and overcome the impacts of a disaster event.

Hence, our framework comprises of three components:

- The ***relative exposure*** of the community to the hazard, i.e. how much of the community's infrastructure, houses, population, etc. will be impacted by an event of a certain magnitude and to what extent?
- The community's ***social vulnerability*** to the hazard, i.e. what does the exposed population's profile look like in terms of underlying social conditions?
- The community's ***capacity*** to prepare, respond, recover and adapt to this type of disaster risk, i.e. what capacity does the exposed population have in terms of reducing their vulnerability?

Community resilience is thus defined in this paper as a measure combining relative exposure, social vulnerability and the community's capacity to prepare, respond, recover and adapt to disaster risk. Justifications for what to include and exclude as indices under each of these three components was based on: the availability of reliable data at the national level; best practice strategies based on the literature; and, recommendations from the key stakeholders and experts from each jurisdiction.

Relative exposure

Information about the exposure of the LGA to a variety of different perils at a range of magnitudes or likelihoods is required to produce a consistent index of resilience across all LGAs in Australia. For example, data on flooding of a 20-year annual recurrence interval (ARI), 50-year ARI, 100-year ARI and Probable Maximum Flood (PMF) would need to be considered to comprehensively assess an LGA's resilience to flood. In the case of bushfire where recurrence intervals are difficult to calculate, the probability of loss as a function of distance of assets from bushland (Crompton et al., 2010) is an appropriate alternative. That is, the number of exposed assets within 100 m, 200 m, 400 m and 700 m of bushland.

Councils or other government agencies may have exposure data pertaining to other perils at various magnitudes or likelihoods. It is unlikely, however, that all perils have been modelled at all magnitudes or likelihoods. For example, a flood-prone LGA is likely to have modelled flood data for 20 and 100-year ARIs. However, storm surge hazard data may not exist at these ARIs.

Based on discussions with municipal officials in each LGA, the following extreme to catastrophic scenarios were selected:

- Flood –100-year ARI (Maribyrnong)
- Tropical cyclone (storm surge only) –1,000-year ARI (Townsville)

- Bushfire – assets within 400 m of bushland (Kalamunda).

Relative exposure is calculated by overlaying hazard extent with the spatial distribution of community components, as contained in the Geocoded National Address File (G-NAF), RoadNET or any other dataset of interest. The various components of a community that may be exposed include people, buildings (e.g. residential homes, commercial properties, industrial premises and public buildings) and infrastructure (e.g. roads and railways, power stations and dams).

Social vulnerability

Social vulnerability refers to various socio-economic and demographic factors within a community, such as age, occupation, health status or disability, which may exacerbate the effects of an external threat resulting in adverse impacts on a person's life, livelihood or assets (Wisner et al., 2004).

In the Australian context, the Socio Economic Indexes for Areas: Index of Relative Socio-Economic Disadvantage (SEIFA IRSD) is considered to be an appropriate means for comparing disadvantage among geographical areas, and is useful when deciding where funding is most needed (.id, 2013; and pers. comm. P. Carney, Queensland Department of Communities, Child Safety and Disability Services). SEIFA IRSD is developed by the Australian Bureau of Statistics as a summary of the social and economic aspects of the Australian population, collected via the 5-yearly Census of Population and Housing (ABS, 2014). Importantly, this index is derived from sound mathematical principals and is therefore defensible and robust, it is generated for nearly all Australian communities and, it can be used as a predictive measure.

Community capacity to prepare, respond, recover and adapt to disaster risk

As Wisner *et al.* (2004; p.14) postulate, '*the processes that generate 'vulnerability' are countered by people's capacities to resist, avoid, adapt to those processes, and to use their abilities for creating security, either before a disaster occurs or during its aftermath*'. As with vulnerability, resilience has a predictive aspect, whereby a community's capacity for resilience can be measured by assessing certain characteristics (Cannon, 2008).

There have been many tools developed internationally (e.g. UNISDR Disaster Resilience Scorecard for Cities) and a few in Australia (namely the Torrens Resilience Institute Community Disaster Resilience Scorecard Toolkit) to measure community resilience at varying levels. For the purposes of our research, i.e. to develop a robust tool that is relevant to Australia and based on easily accessible and reliable data while avoiding user fatigue, we borrowed various indicators from the UNISDR and Torrens Scorecards, based on 1) the availability of reliable and easily accessible data at a national level and 2) their relevance to disaster resilience in Australia.

These indicators were grouped under five key characteristics of resilience (Table 1), as identified by Cannon (2008) and reiterated by Richardson (2014) and others (e.g. King, 2001, King and MacGregor, 2000, Dufty, 2013, Prior and Eriksen, 2013) within an Australian context.

Table 1: Characteristics and indicators that influence capacity to prepare, respond, recover and adapt to disaster risk.

Characteristics	Indicator
Social wellbeing and community connectedness	Proportion of adults with at least one of four key health risk factors Unemployment rate Welfare dependence rate Crime rate per 100,000 in the population Proportion of people over 15 years who spent time doing unpaid voluntary work through an organization or group in the 12 months prior to the last Census Proportion of people living in the same LGA in 2011 as in the previous Census (2006) relative to the population in 2006
Knowledge and experience	Occurrence (or not) of a similar or greater magnitude event of the same peril in the last 5 years Proportion of people who arrived in Australia from abroad within one year of the last Census Proportion of households with at least 3G mobile coverage
Social protection and governance	Time in years since the last natural hazard event in the LGA caused building damage or loss of life Number of volunteers in the LGA for the response/ control agency Do you have emergency plans in place for this peril of this magnitude? How often are these plans exercised? Do exercises include all relevant stakeholders, including the public? Are plans reviewed after a significant event / season? How frequently are the entire plans updated? Access to goods and services (closest medical facilities, nearest major road) Distance to closest town with a similar or greater population
Self protection	Change in median deflated weekly household income since 2006 Average number of motor vehicles per household
Livelihoods	Economic diversification Proportion of agricultural land impacted Proportion of commercial and industrial land impacted GDP per capita in the LGA as a proportion of the national GDP per capita

The measurement

The measures for relative exposure, social vulnerability and capacity have been standardised as scores on the unit interval, [0,1] enabling them to be independently viewed of one another, or combined to yield a single overall view of the resilience of a given community. A *low* relative exposure implies a disaster safer community, which contributes *positively* to community resilience. Similarly, a *low* social vulnerability score (as we are measuring relative disadvantage) will contribute *positively* to community resilience. On the other hand, a *low* capacity score will contribute *negatively* to community resilience. Taken together, an overall measure of community resilience may be calculated as:

$$Community\ resilience\ score = (1 - Relative\ exposure) \times (1\text{-}Social\ vulnerability) \times Capacity$$

To correct for non-linearity, the computed overall community resilience score is transformed into the *final community resilience score* by the relationship:

$$Final\ community\ resilience\ score = \sqrt[3]{Overall\ community\ resilience\ score}$$

This transformation will produce a final community resilience score that is linear. This, broadly speaking, implies that a community with resilience score *x* in the range [0,1] has twice the resilience of another community which has resilience score ½ *x* (a fundamental property of linear functions).

How appropriate is the framework?

Overall, a higher resilience score is achieved with low exposure, low vulnerability and high capacity. The results reveal that community resilience of the three case study areas is quite similar and generally, very good with scores ranging from 0.7345 to 0.7758 out of 1 (Table 2). However, the aspects that comprise this resilience differ markedly from one area to another. It must be noted though, due to the variance in the magnitude / likelihood scenarios used here, the resilience scores for the three case study areas are not directly comparable. Nevertheless, the individual results for each of the case study areas highlight some interesting features.

Table 2: Summary of component and overall resilience indexes for the three case study areas, where lower exposure and vulnerability (i.e. closer to 0) are good and higher capacity (i.e. closer to 1) is good.

	Exposure	Vulnerability	Capacity	Overall Resilience Score
Maribyrnong	0.0307	0.2168	0.5221	0.7345
Kalamunda	0.2327	0.1332	0.6435	0.7536
Townsville	0.1001	0.1708	0.6258	0.7758

Maribyrnong has the lowest exposure of the three case study areas when calculated for a 100-year ARI flood. There are 169 SA1 areas in Maribyrnong (SA1 are designed as the smallest unit for Census data and have an average population of 400 people) and a total of 87,437 people (Please note: all population data is based on the 2011 Australian Census), 35,421 residential houses and 11,771 commercial and industrial buildings (G-NAF, 2015, Geoscience Australia, no date). In terms of exposure to a 100-

year ARI flood, approximately 1,553 people, 688 residential houses and 191 commercial and industrial buildings would potentially be impacted (Please note: the potential number of people impacted is calculated as the product of the number of residential homes exposed to the peril and the average number of people per household within that SA1. It is therefore an approximation of the exposed population). However, Maribyrnong is the most vulnerable area, based on the SEIFA IRSD index, which has been standardised for the purposes of this study to 0.2168. Based on the indicators Maribyrnong also has the least capacity to prepare, respond, recover and adapt to natural disaster risk, when compared to the other two case study areas.

Of note, Maribyrnong's capacity is limited in terms of social wellbeing and community connectedness due to health risk factors and crime rate. There is a lack of experience of an event of similar or greater magnitude in the last 5 years, in addition to more than 20 years since a natural hazard event caused building damage or loss of life in the LGA. Social protection is also hampered by a lower proportion of volunteers per capita working for the designated response agency. However, due to Maribyrnong's proximity to other municipalities of similar or larger size, this might not be an issue when an event occurs as State Emergency Service volunteers can be easily called in from other units if the event does not impact the greater Melbourne area. Also, the potential capacity for self protection among Maribyrnong residents is high compared to the other two case study areas, since Maribyrnong has a greater change in median deflated weekly household income since 2006.

The results show that Kalamunda's exposure to a severe bushfire that has the potential to impact assets within 400 m of the bushland interface is greater than a 100-year ARI flood in Maribyrnong and a 1000-year ARI storm surge in Townsville. Kalamunda, with 134 SA1 areas, had a population of 65,121 people, 24,343 residential houses and 984 commercial and industrial buildings (G-NAF, 2015, Geoscience Australia, no date). In terms of exposure of assets to bushfire within 400 m of bushland, approximately 15,865 people, 5,909 residential houses and 114 commercial and industrial buildings would potentially be impacted. Broken down to the various assets, the results show a much higher proportion of people; people in need of assistance; houses; industrial buildings; and, roads and streets will potentially be impacted compared to the other two case study areas.

However, Kalamunda is the least vulnerable of the case study areas, based on the SEIFA IRSD index, which has been standardised for the purposes of this study to 0.1332. Kalamunda also has the greatest capacity to prepare, respond, recover and adapt to disaster risk, with a capacity score of 0.6435. Kalamunda's capacity is higher than the other two case study areas because the crime rate is less than 0.05 per 100,000 people and there are more volunteers per capita working for the response agency. Kalamunda also scores quite well with respect to the proportion of households with at least 3G mobile telephone coverage and among other indicators listed under social protection and governance.

On the other hand, people's livelihoods may need closer attention. While there is good economic diversification, as with Maribyrnong and Townsville, Kalamunda's resilience rates much lower due to the higher proportion of agricultural land that may be impacted. Kalamunda's resilience also rates lower with respect to a lower GDP per capita in the LGA as a proportion of the national GDP per capita. Kalamunda, like Maribyrnong, is located in close proximity to other urban areas.

Townsville is the largest municipality with 448 SA1 areas, 218,586 residents, 85,183 residential homes and 11,234 commercial and industrial buildings (G-NAF, 2015, Geoscience Australia, no date). In terms of Townsville's exposure to a 1,000-year ARI storm surge event, approximately 11,989 people, 5,744 residential houses and 1,121 commercial and industrial buildings would potentially be impacted. As expected, Townsville's capacity is impeded due to its remote location on the north Queensland coast – it rates poorly with respect to access to goods and services and distance to closest town of similar or greater population. Nevertheless, Townsville scores higher with respect to health risk factors, and alongside Maribyrnong, scores well among the livelihood indicators.

The proportion of households with at least 3G mobile telephone coverage is lower in Townsville than other areas. However, because this is calculated at the LGA level it does not accurately represent coverage of the exposed area, which should be higher due to its proximity to Townsville's CBD.

Relative exposure and social vulnerability have been measured at SA1 level. However, most of the indicator variables comprising the capacity to prepare, respond, recover and adapt to disaster risk are recorded at LGA level, with only a few available at SA1. For consistency, it would be ideal if these data were all measured at SA1 level. However, some of the indicators are simply only relevant at LGA level (e.g. the number of personnel (paid and volunteers) working in emergency management within the LGA). Also, some of the indicators are only reported at LGA level, even though data may be collected (but not reported) at SA1 (e.g. welfare dependence or unemployment rate).

It should be recognised that resilience is a complex concept. In an effort to embrace simplicity the framework proposed here omits certain elements, which might be added later if the data becomes available at the national level (and in finer detail – e.g. LGA or SA1 level). For example, the Productivity Commission produces an excellent resource highlighting various aspects of the emergency management sector (SCRGSP, 2015). Various components of this data would be valuable to include as indicators for social protection, e.g. 'Expenditure of emergency service organisations, per person in the population' or 'Full time equivalent salaried personnel in ambulance, fire and SES organisations'. While other components would be valuable indicators for knowledge and experience, e.g. 'Proportion of people that have developed emergency plans in the events of a natural disaster'. However, at the state and territory level, they lack the detailed LGA data to warrant inclusion in this framework.

The strengths of the framework outlined here are in the process of defining resilience to a particular hazard of a particular magnitude rather than presenting it as a broad concept. For example, the framework produced a score of 0.7758 out of 1 with respect to Townsville's resilience to storm surge associated with a tropical cyclone. However, Townsville's resilience score for bushfire may be considerably lower. Understanding these intricacies through definition and measurement highlights specific areas for risk reduction efforts to enhance disaster resiliency.

Are there other indicators we should consider with respect to flood?

It is argued that measuring and understanding resilience is critical to the development of emergency preparedness and mitigation strategies (e.g. Prior and Hagmann, 2014, Becker et al., 2011, COAG, 2011, Cutter et al., 2008, Dale et al., 2011, Harper et al., 2013). In order to produce a measure that is unambiguous and of value, however, it is essential that agencies seeking to measure resilience clearly state their objectives for doing so and how these measures will be used (Hinkel, 2011).

For example, the State Emergency Services might want to gain an understanding of community resilience to flood for a particular catchment. The SES may therefore choose to include other indicators of importance to them and weight certain indicators higher than others. These may include data on public knowledge and experience and/or capacity for self protection, based on surveys conducted by them. They may also include surface area of impermeable surfaces across LGAs or government incentives to promote the installation of rainwater tanks on residential properties within that catchment. Alternatively, the SES may consider knowledge and experience of greater importance than livelihoods. Of course, if it is to be used at the national level across all hazards, consistency is critical especially if it is to be used longitudinally to measure differences in resilience over time.

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[i] Please note: this paper is a summary of the full report entitled 'A National Framework for Measuring Community Resilience to Disaster' by Risk Frontiers (2016). Please contact the lead author, Deanne Bird (deanne.bird@gmail.com), if you would like a copy of the full report.