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THE AUSTRALIAN NATURAL DISASTER RESILIENCE INDEX

Conceptual framework and indicator approach

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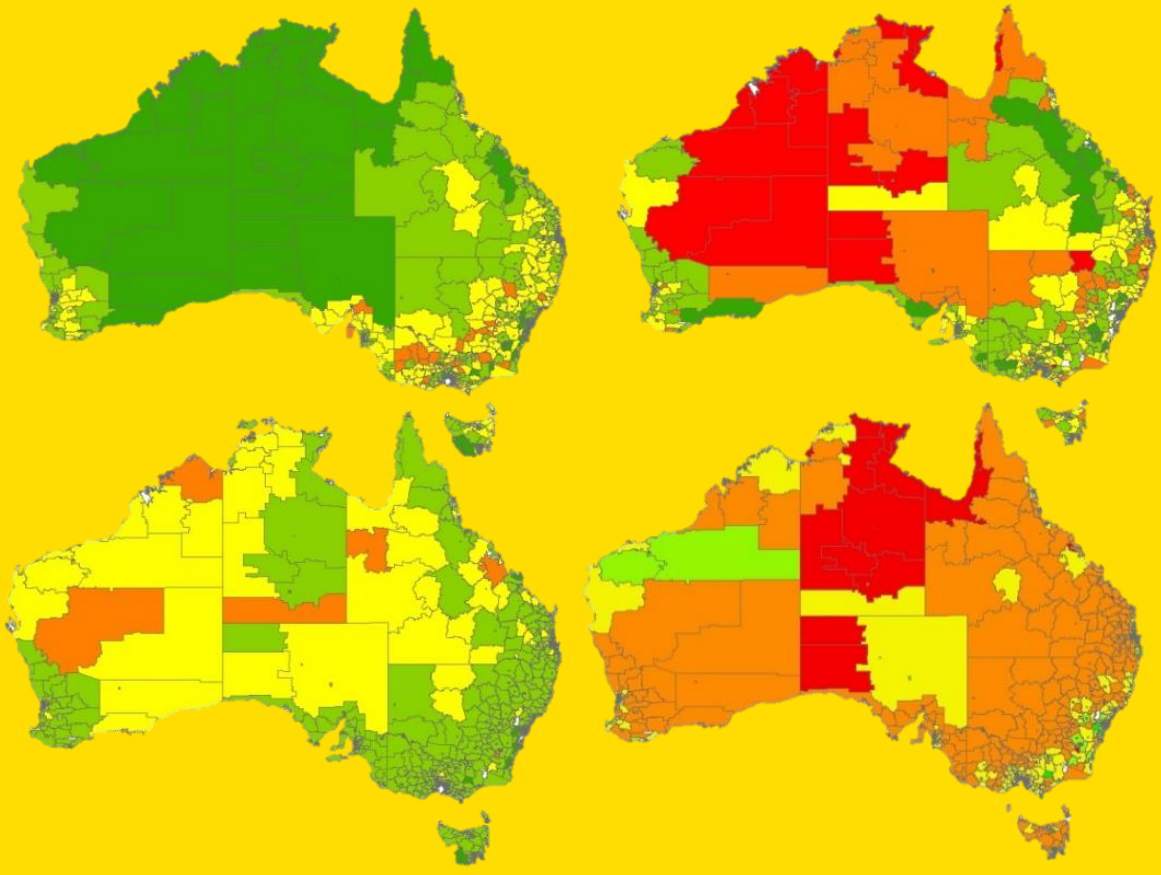

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Cover: Top left, example arrangements of population aged over 75, top right, example arrangements of single parent families, bottom left, example arrangements of households with residents not at same address 1 year ago and bottom right, example arrangements of educational attainment along a continuum of low (red) to high (green) resilience. The scale of resilience is an example only based on equal divisions. Data derived from the ABS 2011 Census.

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END USER STATEMENT

Suellen Flint, Department of Fire and Emergency Services (Western Australia)

At their best resilient communities are prepared, are able to adapt to changing situations, are connected to each other and are self-reliant.

Recent reports into disasters has identified that government has a responsibility to prepare for emergencies, however these reports also identified the notion of shared responsibility. It is clear that government bears a responsibility to support the community to build the knowledge, skills and importantly protective behaviours that are part and parcel of disaster resilience.

Emergency services support its communities by building these characteristics in communities. Not a simple task. It involves highly complex forms of engagement based in a raft of community development based research focused on community and individual psychology, decision making under stress, physiology, knowledge exchange and information take up by the community.

The Australian Natural Disaster Resilience Index will be advantageous in many ways and support National and State and local governments. The ability to identify hot-spots of high or low disaster resilience in Australia, and identify areas of strength in coping and adaptive capacity will support the desired outcomes of the Australian Natural Disaster Resilience Strategy, and potentially help to embed disaster resilience not only into policy and legislation, but to lead to an increase in shared responsibility and resilience across Australia.

I commend the researchers for addressing the challenge in developing the Australian Natural Disaster Resilience Index.

WHY ASSESS DISASTER RESILIENCE IN AUSTRALIA?

Natural hazard management policy directions in Australia – and indeed internationally – are increasingly being aligned to ideas of resilience. There are many definitions of resilience in relation to natural hazards within a contested academic discourse (Klein et al., 2003; Wisner et al., 2004; Boin et al., 2010; Tierney, 2014). Broadly speaking, resilience to natural hazards is the ability of individuals and communities to cope with disturbances or changes and to maintain adaptive behaviour (Maguire and Cartwright, 2008). Building resilience to natural hazards requires the capacity to cope with the event and its aftermath, as well as the capacity to learn about hazard risks, change behaviour, transform institutions and adapt to a changing environment (Maguire and Cartwright, 2008). The shift from a risk-based approach to managing natural hazards towards ideas of disaster resilience reflects the uncertainty associated with predicting the location and impacts of natural hazard events, the inevitability of natural hazard events, and the uncertainty of future natural hazard risks in a changing climate and population.

The emergency management community sits at the forefront of operationalizing ideas of disaster resilience. Australia's *National Strategy for Disaster Resilience* champions a resilience based approach to the challenges posed by natural hazards. Emergency management and other government agencies involved in hazard management are also adopting principles of natural hazard resilience in policies, strategic planning and community engagement (e.g. Queensland Reconstruction Authority, 2012). It is in light of the need to operationalize the concept of disaster resilience that we are developing the Australian Natural Disaster Resilience Index.

The index is a tool for assessing the resilience of communities to natural hazards at a large scale. It is designed specifically to assess resilience to natural hazards – not derived for another purpose then modified to suit a resilience focus. The assessment inputs in several ways to macro-level policy, strategic planning, community planning and community engagement activities at National, State and local government levels. First, it is a snapshot of the current state of natural hazard resilience at a national scale. Second, it is a layer of information for use in strategic policy development and planning. Third, it provides a benchmark against which to assess future change in resilience to natural hazards. Understanding resilience strengths and weaknesses will help communities, governments and organizations to build the capacities needed for living with natural hazards.

There are two principal approaches to assessing disaster resilience using an index. Bottom-up approaches are locally based and locally driven and are qualitative self-assessments of disaster resilience (Committee on Measures of Community Resilience, 2015). Bottom-up approaches survey individuals or communities using a scorecard consisting of indicators of disaster resilience such as preparation, exposure to specific hazards, community resources and communication (e.g. Arbon, 2014). In contrast, top-down approaches are often intended for use at broad scales by an oversight body (Committee on Measures of Community Resilience, 2015) and use secondary spatial sources such as census data to quantitatively derive indicators that describe the inherent characteristics of a community that contribute to disaster resilience (Cutter et

al., 2010). It is important to align the approach used with the purpose of the resilience assessment because bottom-up and top-down approaches both have a point of spatial or conceptual limitation beyond which conclusions about resilience are no longer valid. A framework that outlines the philosophical underpinnings of a project, linked to the mechanisms used to collect and interpret data, can help to scope and define relevant assessment approaches. A framework is an important tool for a resilience assessment because it defines the boundaries - the why, what and how - around the evidence that we use to derive our assessment of natural hazard resilience.

In this document we set out the framework for the Australian Natural Disaster Resilience Index. The framework outlines the conceptual underpinnings of our approach – why we are doing what we are doing – then explains what we will assess about resilience using data aligned to our resilience philosophy. We then briefly explain how we intend to measure these data and the indicators that we will collect to form the index.

OUR APPROACH TO DISASTER RESILIENCE

There are two prominent schools of thought about the influence of natural hazards in human societies. One school of thought derives from a vulnerability perspective where distributional inequalities in physical, social, economic and environmental factors influence the susceptibility of people to harm and the ability of people to respond to hazards factors (Cutter et al. 2003; Birkmann, 2006). The second school of thought derives from a resilience perspective where people are learning to live with a changing, unpredictable and uncertain environment. Human societies interact with their environment and the environment influences human societies within a social-ecological system, of which natural hazards are a part. In this school of thought, resilience is the capacity of a community to cope with disturbances or changes and to maintain adaptive behaviours (Maguire and Cartwright, 2008). Important in this view of resilience is the notion of adaptation, where adaptation and transformation can be proactive for future events, or reactive in response to an event that has already occurred (Handmer and Dovers, 1996; Engle, 2011). Learning from experience and a focus on review and adjustment helps to build resilience to future events.

We have adopted the resilience school of thought for the Australian Natural Disaster Resilience Index (although we do pay heed to the way that distributional inequalities influence resilience). We view resilience as a process linking a set of capacities to a positive trajectory of functioning and adaptation after a disturbance (sensu Norris et al., 2008). The definition of natural hazard resilience that we adopt for the Australian Natural Disaster Resilience Index is:

> *Resilience is the capacity of communities to prepare for, absorb and recover from natural hazard events and to learn, adapt and transform in ways that enhance these capacities in the face of future events.*

Implicit in this definition are three important elements of the index. First, we are concerned with capacities – or potential – for resilience, not the actual realization of resilience in a particular hazard event (Norris et al., 2008). However, information about the realization of resilience can be used to validate potential resilience and refine the index components. Second, learning, adaptation and transformation are vital to resilience because they provide a strategic feedback loop back to the capacities of preparation, coping and recovery (Berkes, 2007; O'Neill and Handmer, 2012). Learning, adaptation and transformation are also mechanisms for adjusting responses and behaviour and provide flexibility for facing an uncertain, unpredictable future (Berkes, 2007). Flexibility is an important element of disaster resilience because natural hazard events will continue to occur, but we do not know where, when, or of what magnitude these events will be. Third, we also use the term natural hazard events rather than natural disasters because with appropriate preparation, natural hazard events can occur but not result in natural disasters (Annan, 2003). However, the terms natural hazards and natural disasters are sometimes used interchangeably to mean any natural hazard event – floods, fires, storms, tsunami, cyclones and so forth – that potentially disrupt and cause loss in society. Natural disaster is also a preferable term for communicating with the general public.

The Australian Natural Disaster Resilience Index will assess resilience based on two sets of capacities – coping capacity and adaptive capacity:

- Coping capacity enables people or organizations to use available resources and abilities to face adverse consequences that could lead to a disaster (sensu UNISDR, 2009). In a practical sense, coping capacity relates to the factors influencing the ability of a community to prepare for, absorb and recover from a natural hazard event.
- Adaptive capacity is the ability of a system to modify or change its characteristics or behaviour to cope with actual or anticipated stresses (Folke et al., 2002). Adaptive capacity entails the existence of institutions and networks that learn and store knowledge and experience, create flexibility in problem solving and balance power among interest groups (Folke et al., 2002). In a practical sense, adaptive capacity relates to the factors that enable adjustment of responses and behaviours through learning, adaptation and transformation.

Together, these coping and adaptive capacities form the core of our assessment of resilience to natural hazards (Figure 1). Coping capacity and adaptive capacity help to answer the question 'How able is a community to prepare for, respond to and recover from a natural hazard event and return to a satisfactorily functioning state in a timely manner, and to strategically learn and adapt to improve its resilience to future natural hazard events?'

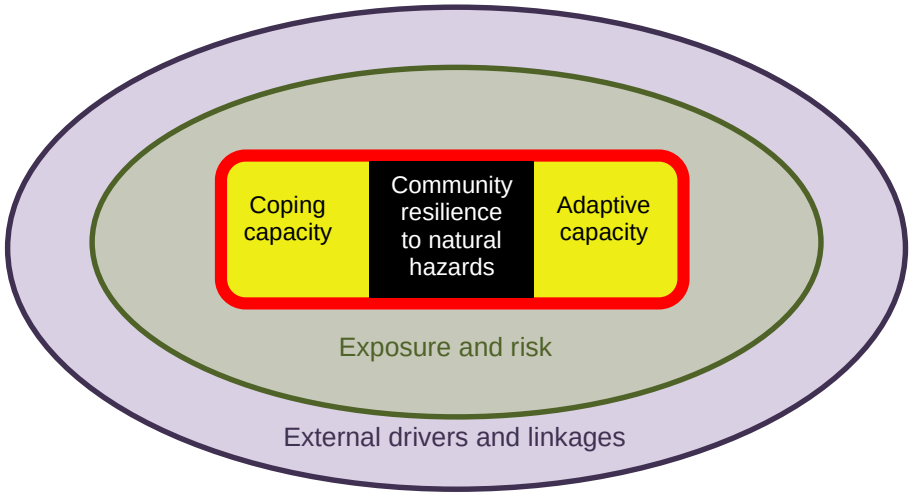

Figure 1. Conceptual model of the Australian Natural Disaster Resilience Index. Factors bordered by the red box are the two sets of capacities that form the index – coping capacity and adaptive capacity. Exposure and risk, and external drivers and linkages are contextual factors that influence disaster resilience but are not included in the index.

The conceptual model also reveals how coping and adaptive capacity are not independent of two important contextual factors. The first of these contextual factors is risk and exposure (Figure 1). Risk expresses the probability and potential loss from natural hazards. Risk assessment is the process of identifying, analysing, evaluating and treating the risks of natural hazard events. Aligned to risk is the concept of exposure. Exposure is the spectrum of natural hazards that occur at different geographical locations and at different magnitudes. We

have deliberately excluded risk and exposure from the assessment of resilience to natural hazards. This is a potential point of contention arising from our approach – how can we assess resilience to natural hazards without knowing what risks we need to be resilient to in different parts of Australia, how likely we are to face them, and what losses might occur? We intend for the Australian Natural Disaster Resilience Index to be able to be overlain with risk maps developed as part of risk assessment and planning (although this overlay step is not part of this project). An all-hazards setting also requires that the assessment considers multiple natural hazards. Not all types of natural hazards occur in all locations in Australia, but the index will assume that the capacities that enable community resilience to one type of natural hazard also enable resilience to other types of natural hazards.

The second contextual factor that influences capacities of resilience is external drivers and linkages (Figure 1). External drivers and linkages include Commonwealth, State and regional policies or legislation in areas such as emergency management, regional development, natural resource management, critical infrastructure and land use planning. External drivers and linkages also encompass broad conditions that influence the characteristics of communities, such as demographic and economic trends.

It is also important to define what we mean by the term community. A community can be seen as sharing a common place or location (Jenkins, 2013). A community can also be seen as sharing a common interest, or a common attachment (Jenkins, 2013). In this project we take the first view of community – that is, a community shares a common location. This view is further moderated by the finest resolution at which we are collecting data –Statistical Area Level 2 area in the Australian Bureau of Statistics census data.

AN INDEX TO ASSESS DISASTER RESILIENCE IN AUSTRALIA

Assessment refers to a qualitative or quantitative process of evaluating the status of some phenomenon of interest. Assessments can be conducted for different purposes including: 1) to gauge or audit the state of a system at one point in time or over time; 2) to assess whether regulated performance criteria have been exceeded; 3) to detect impacts; and, 4) to assess responses to mitigation or restoration (Downes et al., 2002). We take assessment to mean gauging or auditing the state of disaster resilience in a system at one point in time. Resilience to natural hazards can be assessed using indicators of the components of resilience - in this case coping and adaptive capacities – and combined to form an index. An index is a way of summarizing and reporting complex relational measurements about a particular issue. An index should capture change and respond directionally according to the behaviour of the system (Burton, 2015). As such, an index can be arrayed along a continuum of good to poor condition. The status of an index along the continuum can be used as a baseline against which to measure change through time, or change following intervention or treatment.

There are several well-known top-down indexes used in the field of natural hazard assessment. The work of Susan Cutter and her US colleagues began in the 1980s as an index of vulnerability to natural hazards (Cutter et al. 1993), but has evolved further into an index of disaster resilience (Cutter et al., 2008; Cutter et al. 2010). The European emBRACE project reviewed the concepts of resilience and indicators of resilience (Birkmann 2006) and applied these in several case studies of European natural hazard events. Sherrieb et al (2010) assessed capabilities for community resilience in the US Gulf States using a set of resilience indicators. The World Risk Index (Alliance Development Works, 2014) assesses the comparative vulnerability of individual countries to natural hazards using an index approach. We reviewed these (and other) indices and their conceptual bases and concluded that we could not directly adopt an existing top-down, large scale approach to assess disaster resilience in Australia, for several reasons. First, these indices have been developed overseas under different hazard, socio-economic, governance and policy circumstances to Australia. Second, none of the indices were designed to explicitly assess disaster resilience in the way that we conceptualize it – being a set of coping and adaptive capacities. For example, the need for adaptive and flexible organizations has been proposed as an important factor in disaster resilience, but this is often not included in existing indices. However, we do not by any means ignore the important body of assessment research that has come before and there is much overlap in concept, approach and methods between the Australian Natural Disaster Resilience Index and existing indices. We draw on the philosophical underpinnings and methods of assessment of these existing indexes and incorporate them into our assessment of Australian disaster resilience.

There is also an important difference between an index and indicators. An index conveys the overall status of the issue at hand. It can be reported as one number, or more commonly, as sets of numbers related to themes. These themes should be related to the purpose of the index as described by the

underlying philosophical approach – in this case, resilience. Indicators are variables that are used to 'indicate', or measure, the status of the theme. Resilience is not always a directly observable phenomenon, particularly in a top-down, large scale approach (Tate, 2012) and proxies can be used to convey an indicator when the relationship between the proxy and the phenomenon of interest is known. In addition, disaster resilience is influenced by many factors, often with complex interactions. Thus, a robust index requires careful design of component indicators. The structural design of an index can be deductive, hierarchical or inductive. The choice of structure depends largely on the formulation of the conceptual framework but the type of structure used can affect the robustness of individual indicators and the overall index (Tate, 2012).

We have used a hierarchical structure for the Australian Natural Disaster Resilience Index (Figure 2). A hierarchical structure allows levels with similar concepts, processes and spatial/temporal organization to emerge. Lower levels can be summarized into higher levels, and higher levels constrain the elements of levels sitting within it. The first level in our hierarchy is made up of the adaptive capacities and coping capacities that make up our conceptual premise of disaster resilience. The second level in our hierarchy is made up of themes that convey the components of adaptive capacity and coping capacity. The third level is comprised of indicator sets that measure the status of a theme. It is possible that one indicator is relevant across different themes or capacities.

Figure 2. The hierarchical structure of the Australian Natural Disaster Resilience Index. Indicator themes (blue boxes) and component indicators (orange boxes) are outlined in Section 3.1 and 3.2.

INDICATOR THEMES

Themes divide coping capacity and adaptive capacity into its sub-components. Themes are the factors – related to coping capacity or adaptive capacity – that contribute to community resilience to natural hazards. Themes have a basis in the literature: some with empirical evidence of the relationship between the theme and resilience, and others that conceptualize this relationship but with little empirical testing. We will account for these different evidences, and associated uncertainties, as we produce the index (see Section 3.2).

Coping capacity is comprised of six themes that encapsulate the factors influencing the resources and abilities that communities have to prepare for, absorb and recover from natural hazard events (Table 1). Adaptive capacity is comprised of two themes that encapsulate the factors that enable institutional and social learning, flexibility and problem solving (Table 2). The relationships between the theme and natural hazard resilience are established through the literature, where quantitative and qualitative studies explain the resilience responses of communities. Gathering the evidence for the relationship between a theme, or component indicator, is an important part of the study and is explained further in Section 3.2.

INDICATORS

Indicators provide the data for a theme – together the indicators measure the status of the theme. Many indicators have a basis in the literature and have demonstrated relationships with aspects of natural hazards or disasters. For example, there is a documented relationship between income, housing type and gender and the ability to prepare for and respond to natural hazard events (Morrow, 1999). Selecting indicators is both an art and a science. The indicators used to measure the status of the theme can be selected using a set of criteria that increase confidence in the associations between an indicator and disaster resilience (Winderl, 2014). While there will always be trade-offs between indicator specificity, data availability, cost effectiveness and sensitivity (Winderl, 2014) the selection of indicators can be guided by criteria that help to bound large sets of potential indicators. The criteria used to guide the selection of indicators are outlined in Table 3. These criteria will guide the selection of indicators for the Australian Disaster Resilience Index. Several criteria will be more prominent in guiding this selection. First, the data used for the indicator needs to have a whole of nation geographic coverage (Criteria 3, 4 and 6) such as from census data, policy documents or economic data. Second, there will be statistical challenges or requirements that may require us to modify the indicators included in each theme (Criteria 5). Third, the indicator needs to be supported by evidence of how it contributes to resilience and how it behaves along a continuum of low to high resilience, including any verification of the indicator in independent studies (Criteria 1, 2 and 5).

Table 1. Explanation of coping capacity themes within the Australian Natural Disaster Resilience Index. The right hand column overviews the relationship between the theme and natural hazard resilience, although a review process will further explore these relationships as part of the project

Theme	Description	Influence on natural hazard resilience
Social character	• The social characteristics of the community. • Represents the social and demographic factors that influence the ability to prepare for and recover from a natural hazard event.	• Gender, age, disability, health, household size and structure, language, literacy, education and employment influence abilities to build disaster resilience (Morrow, 1999; Thomas et al., 2013).
Economic capital	• The economic characteristics of the community. • Represents the economic factors that influence the ability to prepare for and recover from a natural hazard event.	• Access to economic capital may be a barrier to resilience building activities (Bird et al., 2013). • Losses from natural hazards may increase with greater wealth, but increased potential for loss can also be a motivation for mitigation. • Economic capital often supports healthy social capital (Thomas et al., 2013).
Infrastructure and planning	• The presence of legislation, plans, structures or codes to protect infrastructure. • Represents preparation for natural hazard events using strategies of mitigation or planning or risk management.	• Considered siting and planning of infrastructure is an important element of hazard mitigation. Multiple levels of government are involved in the planning process (King, 2008; Crompton et al., 2010). • Planners can be agents of change in building disaster resilience (Smith, 2009).
Emergency services	• The presence, capability and resourcing of emergency services, warning systems and disaster response plans. • Represents the potential to respond to a natural hazard event.	• Emergency response capabilities and systems support resilience through the entire PPRR cycle.
Community capital	• The cohesion and connectedness of the community. • Represents the features of a community that facilitate coordination and	• Social networks assist community recovery following disaster (Akama et al., 2014). • High levels of social capital can enhance

	cooperation for mutual benefit.	solutions to collective action problems that arise following natural disasters (Aldrich, 2012).
Information and engagement	• Availability and accessibility of natural hazard information, engagement of the community with natural hazards and public-private or other partnerships to encourage risk awareness. • Represents the relationship between communities and information and the uptake of information about risks and the knowledge required for preparation and self-reliance.	• Emergency management community engagement is made up of different approaches including information, participation, consultation, collaboration and empowerment (EMA, 2013). • Community engagement is a vehicle of public participation in decision making about natural hazards (Handmer and Dovers, 2013).

Table 2. Explanation of coping capacity themes within the Australian Natural Disaster Resilience Index. The right hand column overviews the relationship between the theme and natural hazard resilience, although a review process will further explore these relationships as part of the project

Theme	Description	Influence on natural hazard resilience
Governance, policy and leadership	• The capacity within government agencies to adaptively learn, review and adjust policies and procedures, or to transform organizational practices. • Represents the flexibility within organizations to learn from experience and adjust accordingly.	• Effective response to natural hazard events can be facilitated by long term design efforts in public leadership (Boin, 2010). • Transformative adaptation requires altering fundamental value systems, regulatory or bureaucratic regimes associated with natural hazard management (O'Neill and Handmer, 2012). • Collaborative learning facilitates innovation and opportunity for feedback and iterative management (Berkes, 2007; Goldstein, 2012).
Community capital and social character	• The cohesion and connectedness of the community and the social and demographic character of a community. • Represents the resources and support available within communities for	• High levels of social capital can enhance solutions to collective action problems that arise following natural disasters (Aldrich, 2012). • Cooperation and trust are essential to building disaster resilience and arise partly through social mechanisms

	engagement, learning and adaptation and the factors influencing the uptake of adaptation information and strategies.	including social capital (Folke et al., 2002; Kaufman, 2012).

Table 3. Generalized criteria for indicator selection. Compiled from Brown (2009), Bene (2013) and Winderl (2014).

Criteria for indicator selection	Requirements
1. The indicator reflects a justifiable element of natural hazard resilience	• The relationship between the indicator and natural hazard resilience has been verified in the academic/professional literature
2. The indicator can track change and variability in natural hazard resilience	• Change in the indicator can be determined and associated with change in resilience spatially and temporally
3. The indicator is relevant to the scale(s) of assessment	• The indicator aligns with the scale at which the assessment is undertaken. There may be a requirement for an indicator to remain valid across scales (e.g. local to national).
4. The indicator is measurable and readily interpretable	• The indicator is specific and precisely defined. • The indicator is quantifiable and spatially referenced • The indicator is easy to define, understand and communicate
5. The measurement method for the indicator is robust	• Measurement is reliable (and verifiable) and representative of reality • Measurement occurs regularly enough for the purpose • Measurement is methodologically sound
6. The indicator is achievable – data are available, accessible and cost effective	• Data are available at the required scales across most of the study area • Data are readily available from secondary sources • Data can be accessed within the cost and resource framework

A literature review revealed many indicators that have been used to assess disaster vulnerability or resilience in top-down, large scale approaches (e.g. Cutter et al. 2003, Cutter et al. 2010, Sherrieb et al. 2010, Birkmann et al., 2012, Frazier et al., 2013, Orencio and Fujii, 2013). These indicators describe factors influencing disaster resilience, including economic capital, social capital, dwelling type, dwelling tenure, family structure, health and well-being, infrastructure, institutions and demographics. We used these indicators as a basis for identifying potential indicators for the Australian Disaster Resilience Index. Most of the published indicators are aligned with the coping capacity part of the conceptual model (Figure 1). This arises largely from the conceptual approaches that have been used in the aforementioned large scale assessments, where resilience is viewed as the capacities of communities to absorb and moderate the impacts of natural hazards (e.g. Cutter et al. 2010, Sherrieb et al. 2010). The idea of adaptive capacity and the agency of societies to transform and learn in the face of natural hazards is a newer conception in

large scale assessment, although it has been a core theme of the theoretical literature on disaster resilience (Engle, 2011). Deriving indicators of adaptive capacity in relation to natural hazards is even rarer. For example, Cutter et al. (2010) did not attempt to include adaptive capacity indicators, despite adaptive capacity being part of the BRIC Model (Cutter et al., 2008). However, much attention has been paid to the assessment of adaptive capacity in the climate change literature (Engle, 2011; IPCC, 2012). We will explore the climate change adaptation approach as the basis for deriving adaptive capacity indicators, refining to suit the definition associated with natural hazard adaptation. Table 4 outlines the draft set of indicators which will be explored under each theme and capacity. These are not necessarily the final indicators that will be used in the index, as data availability, sensitivity and relationship to natural hazard resilience may result in some modifications. Nonetheless, these are the indicators that we will begin the process of index calculation with. It is also important to note here that each indicator has associated with it a variable (or variables) forming the data set. The variables are defined by the type of data available for each indicator. For example, the indicator educational attainment (Table 4) is comprised of the variable 'Ratio of population with high school education to post-secondary education' calculated from the Australian Bureau of Statistics 2011 Census data on population. The types of variables used as the data for each indicator depend on data availability at the whole-of-Australia geographic scale of assessment.

The generalized process for indicator selection, literature review and index calculation is given in Figure 3. Sitting alongside the selection of indicators will be a process of determining the relationship between the indicator and resilience. There can be a positive or negative relationship between an indicator and natural hazard resilience. For example, families with a large number of dependents often do not have the financial resources to prepare for natural hazard events (Cutter et al. 2003) and renters also may not be able to make modifications to premises that may confer resilience (Morrow, 1999). Quantitative and qualitative studies will be reviewed to extract evidence for the relationship between the indicator and resilience. Both peer-reviewed and grey literature will be considered, as will Australian and international studies. A data set will be established and meta-analysis techniques used to set the relationship between an indicator and resilience, with confidence bounds. This will determine the directionality of the indicator along a continuum of high to low resilience.

Table 4. Proposed indicators of coping and adaptive capacity in the Australian Natural Disaster Resilience Index. Where variables have not yet been derived, a potential data source is given and marked *. ABS = Australian Bureau of Statistics.

Theme	Indicator	Variables and/or data source
	COPING CAPACITY	
Social character *(Social and demographic factors that influence ability to prepare for and recover from natural hazard events)*	Educational attainment	Ratio of population with high school education to post-secondary education
	Age	Percentage of population aged over 75 Percentage of population aged under 15 Median age of population
	Language proficiency	Proficiency in spoken English / language
	Migration (external)	Percentage of population arrived in Australia after 2001
	Migration (internal)	Percentage of households with one or more residents having a different address one year ago
	Gender	Ratio of males to females in population
	Household structure	Percentage of households with children Percentage of households lone person households Percentage of households single parent households
	Core need for assistance	Percentage of population with a core activity need for assistance
	Employment	% labour force employed % not in labour force
	Occupation	% population with occupation as Class 1 or 2
Economic capital *(Economic factors that influence ability to prepare for and recover from natural hazard events)*	Income	% population with income above average weekly earnings Income equity
	Infrastructure	State of the assets report – local government*
	Single-sector employment dependence	ABS economic data*
	Growth	ABS 2011 census and economic data*
	Business wealth	ABS economic data*
	Car ownership	ABS 2011 Census*
	Home ownership	% population home owners
Infrastructure and planning *(Preparation for natural hazard events using strategies of mitigation or planning)*	Building codes	Australian Building Codes board and State level planning legislation*
	Dwelling type	ABS 2011 Census*
	Municipal service levels	Local government national report*
	Land use planning policy	Individual state planning legislation*

	Risk assessment and management strategy	Individual state emergency management legislation and policy*
	Insurance	ABS Household expenditure survey*

Table 4 (cont.)

Theme	Indicator	Variables and/or data source
COPING CAPACITY		
Emergency services *(The presence, capability and resourcing of emergency services, warning systems and disaster response plans)*	Health services	Australian Institute of Health and Welfare*
	Emergency service capability	AFAC and State emergency service agencies* Productivity Commission*
	Emergency service volunteerism	AFAC*
	Remoteness	ATO Remote area allowance categories*
	Disaster response planning and policy	AFAC and State emergency service agencies*
Community capital *(The cohesion and connectedness of the community)*	Crime	Australian Bureau of Criminology*
	Well-being	Australian social health atlases of Australia*
	Access to social services	Australian social health atlases of Australia*
	Sport and recreation	ABS Survey of participation in sport and physical recreation*
	Volunteerism	ABS 2011 Census*
	Length of residence	ABS 2011 Census*
	Environmental quality	Australian State of the Environment Report or National Land and Water Resources Audit*
Information and engagement *(Availability of natural hazard information, community engagement and partnerships to encourage risk awareness)*	Internet connection	ABS Household use of information technology survey*
	Community engagement strategy	Emergency service agency expenditure on community engagement as a proportion of agency budget* Presence and type of emergency service community engagement strategy* Time spent on community engagement*
	Risk awareness strategy and planning	Publicly available risk awareness tools*
ADAPTIVE CAPACITY		
Governance, policy and leadership *(Organizational enablers of adaptation)*	Organizational structure and flexibility	Emergency agency policy* Emergency agency enterprise agreements* Emergency agency budgets*
	Review and learning processes in relation to responsibility	Emergency agency policy and procedures*
	Partnerships (public-private)	Emergency agencies*
	Research and development	Emergency agency budgets*
	Organizational innovation	Emergency agency policy development history*

		Age of legislation and development process
	Trust	Australian or State government surveys*
Community and social engagement *(Social enablers of adaptation)*	Civic engagement	AEC electoral participation data – Federal, State, Local
	Community flexibility	SEIFA*
	Capacity for community self-organization	SEIFA*

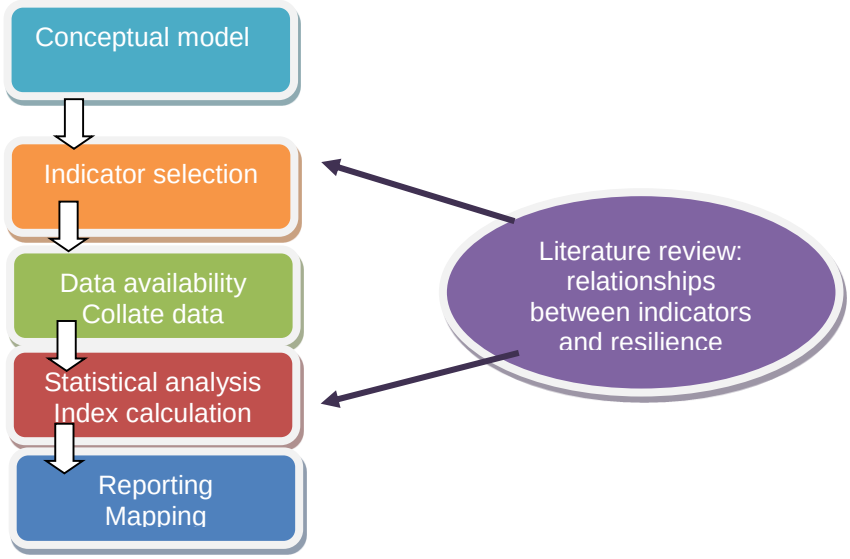

Figure 3. The generalised process for deriving the Australian Natural Disaster Resilience Index.

Index calculation is the process of bringing together the indicators to form an index. There is much debate in the literature about the derivation of an index from component indicators, and the relationship between an index and reality (Tate, 2012; Burton, 2015). Deductive and hierarchical designs tend to use additive models of index derivation. Weighting may be applied to emphasise some indicators with greater contribution to resilience, although weighting strongly influence index sensitivity (Tate, 2012). Inductive designs (e.g. Cutter et al. 2003) use factor analysis to extract factors describing the relative contribution of indicators to overall variation. Factor analysis is sensitive to the choice of indicator set (Tate 2012). Recent symposia suggest that index designs are leaning towards deductive designs that use simple but robust additive models, because these facilitate more meaningful communication of index results. We will explore the outcomes of these two types of approaches on the results of the index. Validation against reality is an element of index design that is developing, because the opportunities for validating assessments of resilience against real events are rare (but see Burton, 2015 for an exception). The extensive literature review supporting each indicator will help to link smaller-scale, hazard-specific observations of the factors thought to influence resilience with the larger-scale index outputs.

WHAT WILL THE AUSTRALIAN NATURAL DISASTER RESILIENCE INDEX LOOK LIKE?

The Australian Natural Disaster Resilience Index is a spatial representation of the current state of disaster resilience across Australia. It will be composed of multiple levels of information that can be reported separately – an overall index, themes and indicators. Information will be conveyed primarily as maps that are colour coded along a continuum of high to low resilience status (see Figure 4 for an example). The index will cover Australia. This means that each point on a map will have a corresponding set of information about natural hazard resilience. Where possible the resolution at which we calculate indicators is the Statistical Areas Level 2 (SA2) division of the Australian Bureau of Statistics (ABS). For data that are not available at this level we will then move up in resolution to the Statistical Areas Level 3 (SA3) division of the ABS. Some indicators may also need to be derived at the Local Government Area level, or even at the regional or state level. Part of our work in the data collection phase of the project will be to examine the sensitivity and comparability of data collected at different scales. The index and indicators will be drawn together as a State of Disaster Resilience Report. This document will interpret resilience at multiple levels and highlight hotspots of high and low elements of natural hazard resilience.

We also intend for the Australian Natural Disaster Resilience Index to be used as a layer of information in the preparation, prevention and recovery spheres. These activities might include policy development, strategy development, risk assessment and management, land use planning, community engagement and organizational planning and prioritization. Spatially explicit capture of data (i.e. in a Geographical Information System) will facilitate seamless integration with other types of information and mapping. These spatial data layers will be a product of the project. However, the relationship between risk and resilience is not necessarily linear and further research will be required to associate the index to risk assessment tools. It is also important to note that the Australian Natural Disaster Resilience Index is not information that supports operational decision making during response to an incident.

In any top-down large-scale assessment such as the Australian Natural Disaster Resilience Index there will be limitations on the currency and application of the findings. Broad national data sets such as the 2011 Australian census will be 7 years old when the index is released in 2017/18. The next Australian census is scheduled for 2016 but it can take several years for some variables to be validated and released by the Australian Bureau of Statistics. There is also a ceiling spatial resolution at which the disaster resilience index can be applied. For example, the index will explain variation in resilience at the smallest resolution of SA2 level of the 2011 Australian census, and some variables may be collected at a broader resolution. Some community planning and engagement activities might ideally like to have finer scale information related to household preparedness activity or street level neighbourliness. This type of data is not collected in the index and indeed, requires a bottom-up survey approach that is outside the scope of this project. Rural, remote and indigenous communities may also experience resilience differently to urban and regional communities. The social influences on rural and remote communities may need to be

accounted for in deriving indicator variables and this will be part of the analysis process.

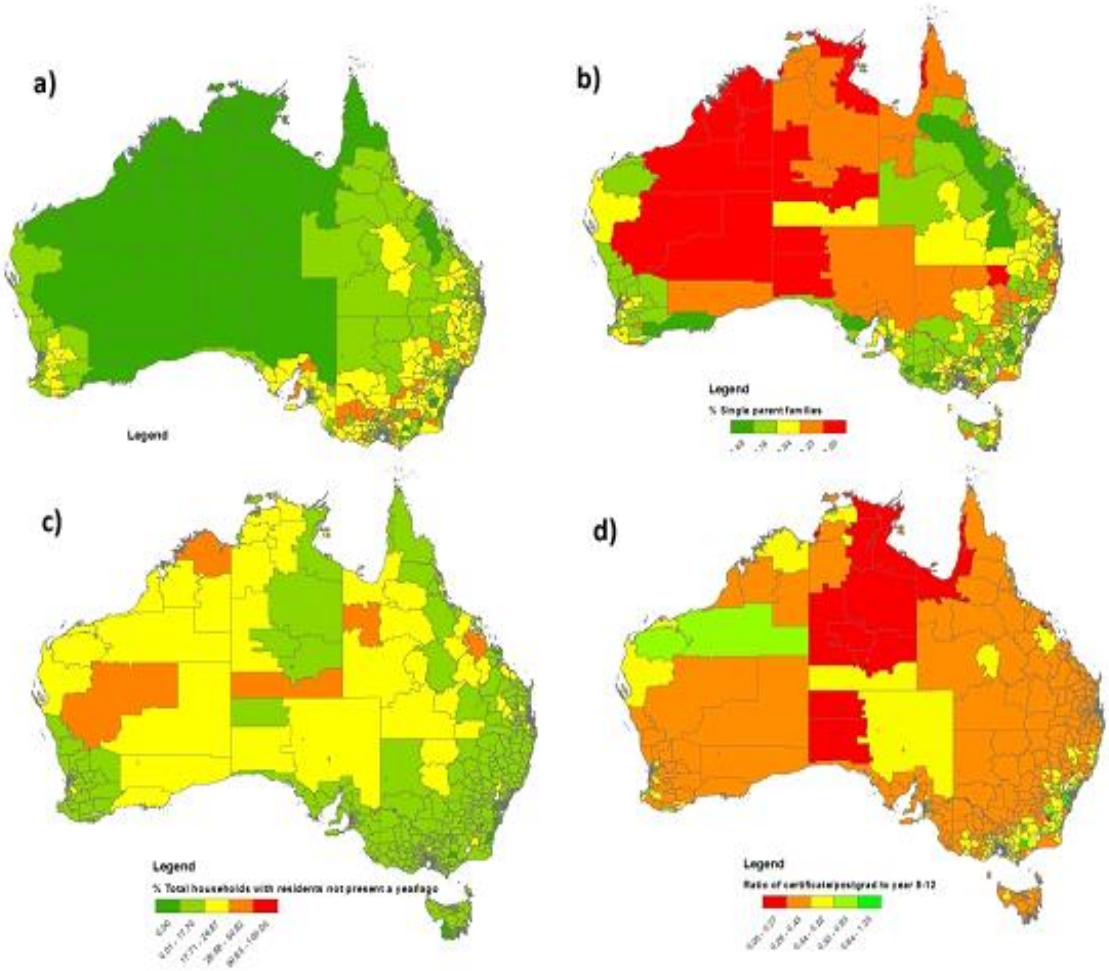

Figure 4. Example arrangements of a) population aged over 75, b) single parent families, c) households with residents not at same address 1 year ago and d) educational attainment along a continuum of low (red) to high (green) resilience. The scale of resilience is an example only based on equal divisions. Data derived from the ABS 2011 Census.

The Australian Natural Disaster Resilience Index also has great benefits. It will provide a tool to assist the move from disaster risk reduction towards a sustainable future of natural hazard resilience (Committee on Measures of Disaster Resilience, 2015). There are many challenges in operationalizing resilience (Klein et al., 2003), particularly through a resilience index. However, the idea of disaster resilience is here to stay (Norris et al. 2008). The Australian Natural Disaster Resilience Index will be advantageous in many ways and support National and State strategic interests in natural hazard management. The index will provide a benchmark of national-level disaster resilience against which future changes can be assessed. It will evaluate hot-spots of high or low disaster resilience in Australia, and identify areas of strength in coping and adaptive capacity. It can also support various policy development initiatives such as the Australian Natural Disaster Resilience Strategy, and potentially help

to embed disaster resilience into policy and legislation. It can also be used as a layer in risk assessment that overlays the socially based influences on disaster resilience.

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