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Disaster resilience in Australia: A geographic assessment using an index of coping and adaptive capacity

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A R T I C L E I N F O

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A B S T R A C T

This paper reports a national-scale assessment of disaster resilience, using the Australian Disaster Resilience Index. The index assesses resilience at three levels: overall capacity for disaster resilience; coping and adaptive capacity; and, eight themes of disaster resilience across social, economic and institutional domains. About 32% of Australia's population (7.6 million people) live in an area assessed as having high capacity for disaster resilience. About 52% of Australia's population (12.3 million people) live in an area assessed as having moderate capacity for disaster resilience. The remaining 16% of Australia's population (3.8 million people) live in an area assessed as having low capacity for disaster resilience. Distribution of disaster resilience in Australia is strongly influenced by a geography of remoteness. Most metropolitan and inner regional areas were assessed as having high capacity for disaster resilience. In contrast, most outer regional, remote and very remote areas were assessed as having low capacity for disaster resilience, although areas of low capacity for disaster resilience can occur in metropolitan areas. Juxtaposed onto this distribution, themes of disaster resilience highlight strengths and barriers to disaster resilience in different communities. For example, low community capital and social cohesion is a disaster resilience barrier in many metropolitan areas, but higher community capital and social cohesion in outer regional and some remote areas supports disaster resilience. The strategic intent of a shared responsibility for disaster resilience can benefit from understanding the spatial distribution of disaster resilience, so that policies and programmes can address systemic influences on disaster resilience.

1. Introduction

The potential for natural hazards to cause substantial social, economic, and environmental loss is a key public policy challenge for governments worldwide [1]. The global cost of natural disasters averaged USD$212 billion each year in the 10 years to 2018 [2] and climate change is expected to add up to 50% to the global costs of extreme weather events by 2040 [3]. It is within this setting of increasing loss that disaster resilience has become a guiding principle for natural hazard mitigation, preparation, response, and recovery activities worldwide [4,5]. Disaster resilience acts as a protective factor: communities with the attributes of disaster resilience will be better placed to plan for, cope with, absorb, and adapt to natural hazards [6]. Attributes that support disaster resilience include social cohesion and capital, access to economic resources, governance and institutional arrangements, service provision and support, risk awareness, and disaster planning [7–15].

Attributes of disaster resilience are inputs to quantitative indices of disaster resilience. The application of indices to assess disaster resilience is well-established, and many indices have been developed to assess disaster resilience, or related concepts of disaster vulnerability and risk (e.g. Refs. [16–20]). Important considerations for the design of an index include the conceptual framework, the use of top-down secondary data collection or bottom-up participatory data collection, the selection of indicators of disaster resilience attributes and the analysis approach (see detailed discussions in Refs. [9,21–24]. While there is academic debate about the production and interpretation of disaster resilience indices (e.g. Refs. [25–28]), they have emerged as a powerful tool for practitioners in areas of public policy, disaster management, and strategic planning because they can summarize complex information, and provide standardised comparisons among jurisdictions. The picture of disaster

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resilience conveyed by an index can support decision making by identifying areas of different capacity for disaster resilience [9,29]. Parsons et al. [23] conceptualised a top-down index to assess disaster resilience as a system of coping and adaptive capacities. The current paper analyses and reports the application of the index to assess disaster resilience at a national scale in Australia.

Most top-down disaster resilience indices at larger state or national scales are inherently spatial because they compare attributes of disaster resilience between places [9,29]. Large scale assessments of disaster resilience often reveal geographies of risk, vulnerability, capital, governmentality, and equity [18]. For example, assessment of disaster resilience in the south eastern states of the USA highlighted differences between urban and rural areas [30]. Assessment of disaster resilience in Chennai, India, revealed differences between older and newer parts of the city [29]. Thus, resilience indices can be interpreted as both a measure of place-specific antecedent conditions of disaster resilience, and as a narrative of the spatial distribution of disaster resilience. It is the latter which may be most difficult for practitioners to adopt into disaster resilience and risk reduction decisions, because the geography of disaster resilience may intersect with complex governance and public policy challenges.

Australia faces increasing losses from natural disasters [31]. Disaster resilience has been adopted as the guiding principle for government strategy for community preparation, risk reduction, and disaster recovery [4]. The Australian Disaster Resilience Index was developed in collaboration with Australian emergency services agencies to quantify and assess disaster resilience at a national scale. This paper reports the assessment of disaster resilience in Australia, undertaken using the Australian Disaster Resilience Index. We examined patterns of disaster resilience across Australia, and situate the findings in relation to an underlying geography of remoteness that we found strongly influenced the capacities of communities for disaster resilience.

2. The Australian Disaster Resilience Index conceptual model

Readers are referred to Parsons et al. [23] for full details of the development of the conceptual model for the Australian Disaster Resilience Index. In summary, the index blends elements of the networked capacities model [32] and the Disaster Resilience of Place model [6] to assess disaster resilience as a set of coping and adaptive capacities [23]. The index is a top-down hierarchical design [24] with three levels: disaster resilience; coping and adaptive capacity; and, themes of disaster resilience. Disaster resilience is the overall index measure and conveys "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" [23]; p.6). Coping capacity is the means by which people or organisations can use available resources and abilities to face adverse consequences that could lead to a disaster (sensu [33]). Adaptive capacity is the arrangements and processes that enable adjustment through learning, adaptation and transformation (sensu [34]). These capacities represent the potential within the system to anticipate, withstand, and adapt to natural hazards, rather than the actual realization of disaster resilience following any one natural hazard event.

Eight themes were used to conceptualise the social, economic and institutional factors that contribute to disaster resilience [23]. Coping capacity is comprised of six themes (social character, economic capital, emergency services, planning and the built environment, community capital, information access) that encapsulate the resources and abilities communities have to prepare for, absorb, and recover from natural hazard events (Table 1). Coping capacity themes align strongly with the concepts included in many indices of disaster resilience [9,19,21,29,30,35]. Adaptive capacity is comprised of two themes (social and community engagement, governance and leadership) that encapsulate institutional and social learning, flexibility, and problem solving capacity (Table 1). While the resilience attributes of transformation,

Table 1
Description of coping and adaptive capacity themes used in the Australian Disaster Resilience Index. Compiled from Ref. [23] and [36]].

Theme	Description	Relationship to disaster resilience
Coping capacity		
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.	Social and demographic factors have well known influences on capacity to prepare for, respond to and recover from a natural hazard events. These include household and family composition, age, sex, education, employment, disability, language, and length of residence.
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.	Economic capital can facilitate disaster resilience by reducing the losses from natural hazard events. Economic resilience can contribute to the reduction of losses from natural hazard events through improved mitigation and risk management, individual flexibility and adaptation, enhanced recovery, market continuity and business continuity. Losses from natural hazards may increase with greater wealth, but increased potential for loss can also be a motivation for mitigation. A high level of economic capital often goes hand in hand with high levels of social capital.
Emergency services	The presence, capability and resourcing of emergency services. Represents the potential to respond to a natural hazard event.	Emergency management is a core function of government. The capacity for emergency response is integral to community disaster resilience. Emergency management is also a key inclusion in policy guiding disaster resilience and disaster risk reduction. Increasing remoteness implies barriers to the provision of, and access to, services.
Planning and the built environment	The presence of legislation, plans, structures or codes to protect communities and their built environment. Represents preparation for natural hazard events using strategies of mitigation, planning or risk management.	Considered land use planning is a core hazard mitigation strategy in built environments. Good planning policy is essential to reduce risk and enhance resilience. Good planning policy can also reduce future risk. Building codes set construction standards to reduce damage from natural hazards.
Community capital	The cohesion and connectedness of the community. Represents the features of a community that facilitate coordination and cooperation for mutual benefit.	Participation in social networks can enhance solutions to collective action problems. Disaster resilience is enhanced by the ways the sense of community fosters participation, community competency, pro-social behaviour and preparedness through working with others to solve shared local problems. Social capital facilitates disaster resilience before, during and after disasters. Social capital is often highlighted in times of disaster because it is a resource that facilitates collective action for mutual benefit.

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Table 1 (*continued*)

Theme	Description	Relationship to disaster resilience
Information access	The potential for communities to engage with natural hazard information. Represents the relationship between communities and natural hazard information and the uptake of knowledge required for preparation and self-reliance.	Telecommunication and internet access is vital to information sharing through all phases of a disaster. As digital communication has become the default medium for everyday exchanges, information sharing, and access to essential services, the disadvantages of being offline increase. Community engagement activities enable disaster resilience through public participation in decision making about natural hazards. Community engagement has been shown to have direct benefit for community resilience through capacity building, social connectedness, self-reliance, awareness of risk and psycho-social preparation.
Adaptive capacity		
Social and community engagement	The capacity within communities to adaptively learn and transform in the face of complex change. Represents the resources and support available within communities for engagement and renewal for mutual benefit.	Adaptive communities are able to manage complex change. Characteristics of adaptive communities include social engagement, trust, cooperation, learning and well-being.
Governance and leadership	The capacity within organisations to adaptively learn, review and adjust policies and procedures, or to transform organisational practices. Represents the flexibility within organisations to learn from experience and adjust accordingly.	Adaptive institutions have conditions suited to the development of the skills, knowledge and culture for managing complex change. Enabling conditions include social learning, research, innovation, collaboration and leadership. Effective response to natural hazard events can be facilitated by long term design efforts in public leadership.

learning, and adaptive governance are well-understood [34], concepts of adaptation are not often included in disaster resilience indices [28] despite their value for understanding how society might manage complex change and the uncertainty of natural disasters.

3. Materials and methods

The geographic extent of the index is the whole of Australia, and the grain for calculation of the index is Statistical Area Level 2 (SA2), defined in the 2011 Australian Statistical Geography Standard [37]. Each SA2 is delineated using criteria of population, functional areas, growth and gazetted localities and generally has a population of 3000 to 25,000 people [37]. There are 2214 SA2s across Australia. The index was computed for 2084 SA2s: the remaining 130 were excluded because they were areas of no or low population such as ports, national parks or industrial estates, or because of limited data availability for areas such as Lord Howe Island, Christmas Island, and Jervis Bay [38].

3.1. Indicator selection

The index uses a top-down assessment approach, relying on secondary data to form indicators with which to calculate the index. Indicators are the variables used to measure the status of the themes of resilience defined in the conceptual framework. Hundreds of indicators have been used to assess disaster vulnerability or resilience in top-down assessment, but key challenges remain in the availability of quantitative data to operationalise the conceptualisations of vulnerability or resilience, and in determining the directionality of relationship between an indicator and resilience or vulnerability [9,21]. While there will always be trade-offs when selecting indicators of disaster resilience [39,40], selection can be guided by criteria such as a justifiable relationship to resilience, ability to track change, scale relevance, ease of interpretation, robust measurement, and data availability that help to bound large sets of potential indicators (see Ref. [23]).

An iterative process of indicator selection considered data availability, scale relevance, and the relationships between an indicator and disaster resilience. The index required indicator data to have national-scale availability. A comprehensive search was undertaken for national-scale indicators related to the eight themes of resilience identified in the conceptual model, using data which were publicly available or available for a reasonable fee. Data sets from organisations such as the Australian Bureau of Statistics, Australian Institute of Health and Welfare, National Exposure Information System, Productivity Commission, the Regional Australia Institute, Department of Communications, and the Australian Urban Infrastructure Research Network fit this criteria (see Ref. [38]). State-level data sets such as those associated with emergency service agencies and local government were also used if the same data were available across all eight States and Territories of Australia. Relationships between indicators and disaster resilience were examined using a literature review of the attributes of disaster resilience, with some focus on Australian natural hazards, disaster management arrangements and experiences [38]. This step ensured that the proposed indicators were meaningful as attributes of the social, economic, and institutional influences on disaster resilience in Australia. Iterations of indicator selection were guided by the authors (of this paper) with subject matter expertise in urban and regional planning, economics, emergency services, and geography. Data availability or spatial coverage precluded the inclusion of some highly desirable attributes of disaster resilience including insurance, community well-being, institutional leadership, and critical infrastructure protection. Thus, the Australian Disaster Resilience Index is a model of disaster resilience constructed under some constraints of data availability.

A set of 82 indicators were compiled for each SA2 (Table 2). Several indicators were only available for State, region, or local government areas and were disaggregated to SA2 resolution using interpolation techniques based on spatial assignment (Table 2). Where there was no disagreement between the boundary of an SA2 and the boundary of the area corresponding to the indicator data (i.e. SA4, SA3, State) data from the larger area was assigned to each component SA2. Where there was disagreement between boundaries (i.e. Local Government Areas, Police Districts) data from the larger area was matched with a component SA2 using population-weighted (LGA) or areal (Police Districts) concordance. Using the correspondence table of the Australian Bureau of Statistics, 95% of the 2084 SA2s used in the index had a >80% population-weighted concordance with one LGA [38]. The remaining 5% of SA2s were examined on maps to explore boundary explanations (e.g. metropolitan LGA with a boundary running through an SA2) and the SA2 was generally made concordant with the LGA with the highest percent population-weighted concordance. While most indicators were derived from secondary data sources, content analysis of legislation, policy, and organisational documents was used to derive four indicators: emergency planning assessment score, planning assessment score [41], community engagement score; and, emergency services governance, policy and leadership score [38]. The majority of indicators (67) were associated with the coping capacity themes (Table 2). Fewer indicators were available at a national scale to populate the adaptive capacity themes (Table 2).

Table 2
Indicators used to compute the Australian Disaster Resilience Index. Negative resilience directions mean that higher values of the indicator are associated with lower capacity for disaster resilience. Positive directions mean that higher values of the indicator are associated with higher capacity for disaster resilience. ABS = Australian Bureau of Statistics. AIHW = Australian Institute of Health and Welfare. Data treatment details the disaggregation applied to some indicators from larger areas to ABS Statistical Area Level 2 (SA2) resolution, or indicators that were removed as part of index computation because of high correlation with other indicators. Disaggregation methods are described in the text.

Indicator	Resilience direction	Data source	Data treatment
Social character			
% population arrived in Australia 2001 onwards	-ve	ABS 2011 Census	
% households with all or some residents not present a year ago	-ve	ABS 2011 Census	
% speaks English not well or not at all	-ve	ABS 2011 Census	
% population with a core activity need for assistance	-ve	ABS 2011 Census	
% one parent families	-ve	ABS 2011 Census	
% households with children	-ve	ABS 2011 Census	
% lone person households	-ve	ABS 2011 Census	
% group households	-ve	ABS 2011 Census	
Sex ratio	+ve	ABS 2011 Census	
% population aged over 75	-ve	ABS 2011 Census	
% population aged below 15	-ve	ABS 2011 Census	
Ratio of certificate/postgraduate educational attainment to Year 8–12 educational attainment	-ve	Computed from ABS 2011 Census	
% of labour force unemployed	-ve	ABS 2011 Census	
% not in labour force	-ve	ABS 2011 Census	
% employed as managers and professionals	+ve	ABS 2011 Census	
Economic capital			
% residents owning their home outright	+ve	ABS 2011 Census	
% residents owning their home with a mortgage	+ve	ABS 2011 Census	
% residents renting their home	-ve	ABS 2011 Census	
Median weekly rent ($)	-ve	ABS 2011 Census	
Median monthly mortgage repayment ($)	-ve	ABS 2011 Census	
Median weekly personal income ($)	+ve	ABS 2011 Census	
Median weekly family income ($)	+ve	ABS 2011 Census	
% families with less than $600 per week income	-ve	ABS 2011 Census	
% families with more than $3000 per week income	+ve	ABS 2011 Census	
% employment in largest single sector	-ve	ABS 2011 Census	
Economic Diversity Index	+ve	Computed from ABS 2011 Census	
% businesses employing 20 or more people	+ve	ABS Counts of Australian Businesses	
Retail and/or commercial establishments per 1000 people	+ve	ABS Counts of Australian Businesses	
% population change 2001 to 2011	-ve	ABS 2011 Census	
Local government grant per capita	-ve	Department of Infrastructure and Regional Development	LGA to SA2
GINI Coefficient	+ve	ABS Estimates of Personal Income 2012 to 2013	Removed (correlation)
Emergency services			
Medical practitioners per 1000 population	+ve	AIHW National Health Workforce Database 2011	ABS SA3 to SA2
Registered nurses per 1000 population	+ve	AIHW National Health Workforce Database 2011	ABS SA3 to SA2
Psychologists per 1000 population	+ve	AIHW National Health Workforce Database 2011	ABS SA3 to SA2
Welfare support workers per 1000 population	+ve	ABS 2011 Census	ABS SA4 to SA2
Available hospital beds per 1000 population	+ve	AIHW National Health Workforce Database 2011	State and remoteness classes to SA2
Ambulance officers and paramedics per 1000 population	+ve	ABS 2011 Census	ABS SA4 to SA2
Fire and emergency services workers per 1000 population	+ve	ABS 2011 Census	ABS SA4 to SA2
Police per 1000 population	+ve	ABS 2011 Census	ABS SA4 to SA2
Fire and emergency services and SES organisations funding per 1000 population	+ve	Productivity Commission Report on Government Services 2014-15	State to SA2
Ambulance organisations funding per 1000 population	+ve	Productivity Commission Report on Government Services 2014-15	State to SA2
Fire service volunteers per 1000 population	+ve	Emergency Service Agency Reports	State to SA2
SES volunteers per 1000 population	+ve	Emergency Service Agency Reports	State to SA2
Distance to medical facility (km)	-ve	Regional Australia Institute	LGA to SA2
Planning and the built environment			
% caravan and improvised dwellings	-ve	ABS 2011 Census	
% residential dwellings built post 1981	+ve	National Exposure Information System	
% commercial and industrial dwellings built post 1981	+ve	National Exposure Information System	
% residential dwellings built pre 1980	-ve	National Exposure Information System	Removed (correlation)
% commercial and industrial dwellings built pre 1980	-ve	National Exposure Information System	Removed (correlation)
Emergency planning assessment score	+ve	Computed. See Ref. [36] for protocol.	LGA to SA2
Full-time equivalent council staff	+ve	Local Government Reports	LGA to SA2
Council area per full-time equivalent council staff	-ve	Computed from local Government Reports	LGA to SA2
Number of dwellings per full-time equivalent council staff	-ve	Computed from local Government Reports	LGA to SA2
New dwellings (2012–2016) as a	-ve		LGA to SA2

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Table 2 (*continued*)

Indicator	Resilience direction	Data source	Data treatment
proportion of 2011 dwellings		Computed from ABS 2011 and 2016 Census	
New dwellings per week (2015–2016)	-ve	Computed from local Government Reports	LGA to SA2
Local Government Area population per FTE council staff	-ve	Local Government Reports	Removed (correlation)
Road kilometres per FTE council staff	-ve	Local Government Reports	Removed (correlation)
Planning assessment score	+ve	Computed. See Ref. [41] for protocol.	LGA to SA2
Community capital			
Offences against person per 100,000 population	-ve	State and Territory Crime Statistics	Police district to SA2
Offences against property per 100,000 population	-ve	State and Territory Crime Statistics	Police district to SA2
Age standardised number of people per 100 population who feel safe walking in their neighbourhood	+ve	Social Health Atlas of Australia	LGA to SA2
Age standardised number of people per 100 population who are able to get support in times of crisis	+ve	Social Health Atlas of Australia	LGA to SA2
Age standardised number of people per 100 population whose household could raise $2000 in a week	+ve	Social Health Atlas of Australia	LGA to SA2
Age standardised number of people per 100 population who had difficulty accessing services	-ve	Social Health Atlas of Australia	LGA to SA2
% households with no motor vehicle	-ve	ABS 2011 Census	
Age standardised number of people per 100 population with fair or poor self-assessed health	-ve	Social Health Atlas of Australia	LGA to SA2
% residents in same residence for greater than 5 years	+ve	ABS 2011 Census	
% population undertaking voluntary work	+ve	ABS 2011 Census	
% jobless families	-ve	ABS 2011 Census	
Information access			
% area with excellent or good ADSL coverage	+ve	Department of Communications	
% area with mobile phone coverage	+ve	Telstra	
Community engagement score	+ve	Computed. See Ref. [36] for protocol.	State to SA2
Social and community engagement			
% population with life satisfaction scale 70 and above	+ve	AURIN	
% population with high generalised trust	+ve	AURIN	
Migration effectiveness 2006–2011	-ve	Computed from ABS 2011 Census	
% population with post school educational qualification	+ve	ABS 2011 Census	
% population over 15 in further education	+ve	ABS 2011 Census	
% participation in personal interest learning	+ve	ABS 2013 Survey of Work-Related Training and Adult Learning	State to SA2
Governance and leadership			
Presence of research organisations	+ve	Regional Australia Institute	LGA to SA2
Business Dynamo Index	+ve	Regional Australia Institute	LGA to SA2
Local economic development support	+ve	Regional Australia Institute	LGA to SA2
Emergency services governance, policy and leadership score	+ve	Computed. See Ref. [36] for protocol.	State to SA2

3.2. Composite index calculation

The Australian Disaster Resilience Index is a composite index. Composite indices form individual indicators into a single number, and measure multi-dimensional, relational constructs [42]. A composite index was computed for each of the 2084 SA2s and the three hierarchical levels: disaster resilience; coping and adaptive capacity and themes of disaster resilience. An index for each theme was formed from component indicators. Coping and adaptive capacity indices were formed from component theme indices. The overall disaster resilience index was formed from the coping and adaptive capacity indices.

Computation of the index involved two stages: indicator conditioning and aggregation. The conditioning stage adjusts the indicators so that they can be validly combined into an index. Two transformations were applied: normalisation to bring each indicator to a normal distribution if required; and rescaling to bring all indicators to a common range of 0–1. Evaluation of indicators showed that some were extremely skewed and strongly leptokurtic. A power transformation was used to reduce skewness to zero. A rank preserving transformation involving a linear combination of indicator value, rank and an adjustable coefficient was used to reduce kurtosis to close to zero [38]. In both cases a root-finding algorithm was used to find the required exponent and coefficient. Normalised indicators were then rescaled using min-max rescaling. Given that distributional extreme values had been minimised through normalisation, min-max rescaling was preferred over commonly used z-score rescaling since the latter would introduce the standard deviation as an artefact in the transformed indicator. Normalisation and rescaling of indicators was non-linear and rank preserving.

Another aspect of indicator conditioning was to adjust all indicators by their relationship to disaster resilience (Table 2). In general, relationships between an indicator and disaster resilience are equivocal and differ by hazard type and event, or among individuals and communities. Disaster resilience may be improved as the value of a particular indicator increases (positive relationship), or it may be reduced (negative relationship). The relationship between the indicators and disaster resilience was determined using the indicator literature review. Since it was assumed that indicators contribute to the overall composite index in an additive fashion, it was necessary to reverse indicator values where the relationship with resilience was negative. This was achieved with min-max rescaled indicators by subtracting from 1.

Indicator conditioning also removed highly correlated indicators. Principal Components Analysis was used to identify components formed by the indicators in each theme. The presence or absence of a strong multi-component structure was judged by the Kaiser-Meyer-Olkin measure of sampling adequacy [43] and inspection of the sorted loadings table and level plot of the correlation matrix. Where pairs of indicators had a high positive correlation within a component, and the nature of the indicators allowed an interpretation of redundancy, one indicator was removed. Five indicators were removed from the data set: one in the economic capital theme and four in the planning and the built environment theme (Table 2). The final data set contained 77 indicators.

Weighting attempts to bring the concept of relative importance among indicators into the index construction process, although even without purposeful weighting, aggregation can introduce implicit weighting effects into the composite index (as discussed in the justification for using two level formative measurement models below). Equal weighting is widely used in composite index development, justified by the lack of information about the relative importance of indicators (e.g. Ref. [30], or by concerns about the alternatives to equal weighting [44]. However, De Muro et al. [45] point out that whenever additive aggregation is being contemplated the apparently innocuous assumption of equal weighting disguises a strong assumption of perfect substitutability between indicators. The approach taken for the Australian Disaster Resilience Index was to apply no weights prior to the aggregation process (effectively, equal weighting), but to instead focus on the aggregation method to ensure that indicator substitution effects were controlled to the maximum level possible, consistent with current knowledge about possible interactions between indicators.

The aggregation stage combines the indicators into an index. The choice of aggregation methods is influenced by the measurement model used to design a composite index. A formative model is one where the indicators are considered to be the cause of the latent construct (disaster resilience). A reflective model is the reverse, where the latent construct (disaster resilience) causes the indicators. The Australian Disaster Resilience Index is based on a formative measurement model, in which indicators of the factors that are believed to influence the latent characteristic of disaster resilience are aggregated into a composite index that is hypothesised to quantify that latent characteristic. As such, the method of aggregation has to provide a desired degree of control over compensatory relationships among indicators and the extent to which high values of some indicators should be allowed to cancel out low values of other indicators [46]. This control of compensatory relationships is not required with the simple additive forms of aggregation that are used with reflective measurement models in areas such as classical test theory [47]. Reflective measurement models involve indicators that are hypothesised to be affected by a latent variable, and if summed or averaged provide a measure of the latent variable.

Two aggregation functions were used to combine indicators. The discrete Choquet integral [48] was used when aggregation involved two or three indicators and current knowledge was sufficient to specify the interactions between the indicators. Ordered Weighted Averaging (OWA [49]) was used for aggregating four or more indicators, or two and three indicators when the discrete Choquet integral was unable to be used because there was insufficient knowledge to specify the interactions between indicators. The discrete Choquet integral requires that the allowable degree of compensability be specified for every pair of indicators being aggregated, whereas OWA requires only a single generic specification, termed the orness. For aggregations where a reasonable degree of compensation between indicators was judged acceptable, OWA with an orness of 0.375 was used. Where not acceptable, an orness of 0.125 was used. Note that OWA with an orness of 0.5 is equivalent to the mean, and OWA with an orness of 0 is equivalent to the minimum function.

Different strategies of indicator aggregation were applied, depending on the number of indicators contained in a theme and the correlations among them. Where Principal Components Analysis (PCA) of the indicators revealed well defined, interpretable, sub-themes with substantial disparities in the number of indicators in each sub-theme, a two-level strategy involving intermediate sub-indices was used to aggregate indicators, so that the sub-themes with large numbers of indicators did not unduly dominate the theme index. In this strategy, either the discrete Choquet integral or OWA was used as the aggregation function, depending on the number and compensability of the indicators [38]. This strategy was applied to the social character, economic capital, emergency services, planning and the built environment, and social and community engagement themes. In contrast, where PCA did not reveal sub-themes, a one-level strategy with the OWA aggregation function was used. This strategy was applied to the community capital, information access and governance and leadership themes. The one-level strategy was also used to aggregate themes into the coping and adaptive capacity indexes, and to aggregate coping and adaptive capacity into the disaster resilience index. All statistical analyses were conducted using the base R package [50], supplemented with contributed packages including e1071, psych, rgdat, sp and classint for analysis and mapping.

Geographic interpretation of the index involved mapping, tallying the population associated with different index values, and evaluating the index in relation to a remoteness geography. Index values were expressed as a value between 0 and 1, where 0 is low disaster resilience and 1 is high disaster resilience. Bands of disaster resilience were delineated using the <25th (low), 25th – 75th (moderate) and 75th (high) percentiles, based on the distribution of all 2084 index values. Each band has an associated narrative interpretation based on definitions formed in the conceptual model. The remoteness of each SA2 was determined using the Australian Statistical Geography Standard Remoteness Structure [37] consisting of metropolitan, inner regional, outer regional, remote and very remote areas (Fig. 1). Mapping the 2084 SA2s onto the remoteness structure, there are 1203 metropolitan (major cities) SA2s, 476 inner regional SA2s, 309 outer regional SA2s, 48 remote SA2s and 48 very remote SA2s. The population of each SA2 was determined using the Australian Bureau of Statistics Estimated Resident Population as at June 30, 2015. Population, land area, and remoteness characteristics of component SA2s were tallied to estimate the proportions associated with the disaster resilience bands.

4. Results

4.1. Disaster resilience in Australia

The Australian Disaster Resilience Index revealed a non-uniform distribution of capacity for disaster resilience around Australia. Higher capacity for disaster resilience is visibly concentrated into the populated south east area of Australia, or around metropolitan areas (Fig. 2). About 32% of Australia's population, or 7.6 million people, live in an SA2 assessed as having high capacity for disaster resilience (Table 3). Communities in areas of high disaster resilience have enhanced capacity to use available resources to cope with adverse events and enhanced capacity to adjust to change through learning, adaptation and transformation. Areas of high capacity for disaster resilience cover less than half a percent of Australia's land area (Table 3). About 52% of Australia's population, or 12.3 million people, live in an SA2 assessed as having moderate capacity for disaster resilience (Table 3). Communities in areas of moderate disaster resilience have some capacity to use available resources to cope with adverse events and some capacity to adjust to change through learning, adaptation and transformation. Areas of moderate capacity for disaster resilience cover 6% of Australia's land area (Table 3). The remaining 16% of Australia's population, or 3.8 million people, live in an SA2 assessed as having low capacity for disaster resilience (Table 3). Communities in areas of low disaster resilience are limited in their capacity to use available resources to cope with adverse events and to adjust to change through learning, adaptation and transformation. Areas of low capacity for disaster resilience cover 93% of Australia's land area (Table 3).

There is a distinct association between capacity for disaster resilience and remoteness. Most of the SA2s assessed as having high capacity for disaster resilience occur in metropolitan and inner regional areas of Australia (Fig. 3). Only three outer-regional SA2s had high capacity for disaster resilience, and no remote or very remote SA2s fell into this band. Many of the SA2s assessed as having low capacity for disaster resilience occur in outer regional, remote and very remote areas of Australia (Fig. 3), corresponding to a population of about 1.6 million

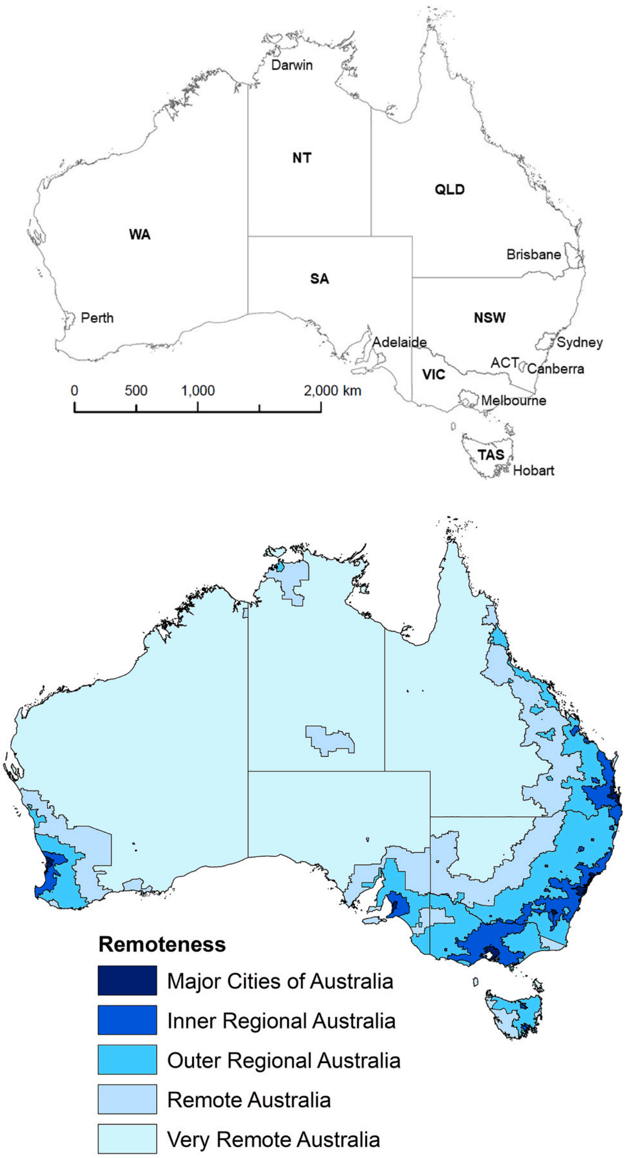

Fig. 1. States, Territories and capital cities of Australia (top) and the remoteness structure (bottom) of the 2011 Australian Statistical Geography Standard [37].

people (2% of Australia's total population). However, SA2s with low capacity for disaster resilience are also found in metropolitan and inner regional areas (Fig. 3), corresponding to a population of about 2.2 million people (8% of Australia's total population). Moderate capacity for disaster resilience is the dominant band for metropolitan and inner regional areas, but also occurs in some outer regional and remote areas (Fig. 3).

4.2. Coping and adaptive capacity

The Australian Disaster Resilience Index also revealed a non-uniform distribution of coping and adaptive capacity around Australia. There is a general pattern of higher coping capacity in metropolitan areas, and higher adaptive capacity in the highly populated south east of Australia (Fig. 4). Coping and adaptive capacity can be considered as combinations that represent the relative antecedent supports for preparation, planning, and adaptation. About 13% of Australia's population, or about 3 million people, live in an SA2 assessed as having high coping and high adaptive capacity (Table 4). Areas assessed as having high coping and adaptive capacity have the antecedent conditions to use available resources to cope with adverse events and to adjust to complex change through learning and transformation. About 7% of the population, or 1.6 million people live in SA2s assessed as having low coping and adaptive capacity (Table 4). Areas assessed as having low coping and adaptive capacity face limitations in using available resources to prepare for, absorb, and recover from natural hazard events and to learn, adapt, and transform in the face of complex change. Areas with the combination of moderate coping capacity and moderate adaptive capacity are associated with 27% of the population, or 6.4 million people (Table 4). Areas with combinations of high, moderate and low coping and adaptive capacity are associated with the remaining 53% of the population, highlighting that there can be a mix of strengths and barriers arising from coping and adaptive capacity in these SA2s.

Patterns of coping and adaptive capacity are also related to remoteness. Most SA2s assessed as having high or moderate coping or adaptive capacity occur in metropolitan and inner regional areas (Fig. 5). However, SA2s with low coping or adaptive capacity also occur in metropolitan and inner regional areas (Fig. 5). Some SA2s in outer regional, remote and very remote Australia have moderate or high coping capacity (Fig. 5a) but no remote or very remote areas are associated with high adaptive capacity (Fig. 5b).

4.3. Factors influencing disaster resilience

Themes of disaster resilience have varied relationships to remoteness. The social character index represents the antecedent demographic conditions that contribute to capacity for disaster resilience. There is a mosaic distribution of the social character index throughout Australia (Fig. 6a). Many metropolitan and very remote SA2s are associated with low values of the social character index and therefore, less capacity for disaster resilience arising from the demographic makeup of the community (Fig. 7a). Areas of moderate and high social character occur in all remoteness classes (Fig. 7a), corresponding to a mosaic pattern of index distribution (Fig. 6a).

The economic capital theme represents the antecedent economic conditions that contribute to capacity for disaster resilience. Higher economic capital is almost entirely confined to SA2s in the highly populated coastal areas and around major capital cities (Fig. 6b). Metropolitan and inner regional SA2s are generally associated with high or moderate economic capital (Fig. 7b). Lower economic capital is associated with increasing remoteness, and a high percentage of outer regional, remote and very remote SA2s were assessed as having low economic capital (Fig. 7b).

The emergency services theme represents how the presence, capability, and resourcing of emergency services contributes to capacity for disaster resilience. There is a concentration of higher emergency service capacity in the more populous eastern states of Australia (Fig. 6c). Metropolitan, inner regional, and outer regional areas have higher proportions of SA2s with moderate to high emergency services (Fig. 7c) although this is principally in the eastern states. Increasing remoteness tends to be associated with lower emergency service capacity (Fig. 7c) but this is most prominent in the western states (Fig. 6c). This suggests a bifurcated pattern among eastern and western states in the way that emergency services contribute to the capacity for disaster resilience.

The planning and the built environment theme represents the contribution of planning, mitigation or risk management to the capacity for disaster resilience. Capacity in planning and the built environment is relatively high across most of Australia (Fig. 6d). Metropolitan, inner regional, and outer regional areas generally have high to moderate planning and the built environment capacity (Fig. 7d). Increasing remoteness is again associated with lower planning and the built environment capacity (Fig. 7d) potentially indicating a lack of integration or oversight in systems of planning for natural hazards in more remote areas. However, many metropolitan SA2s were associated with low planning and the built environment capacity (Fig. 7d), suggesting that

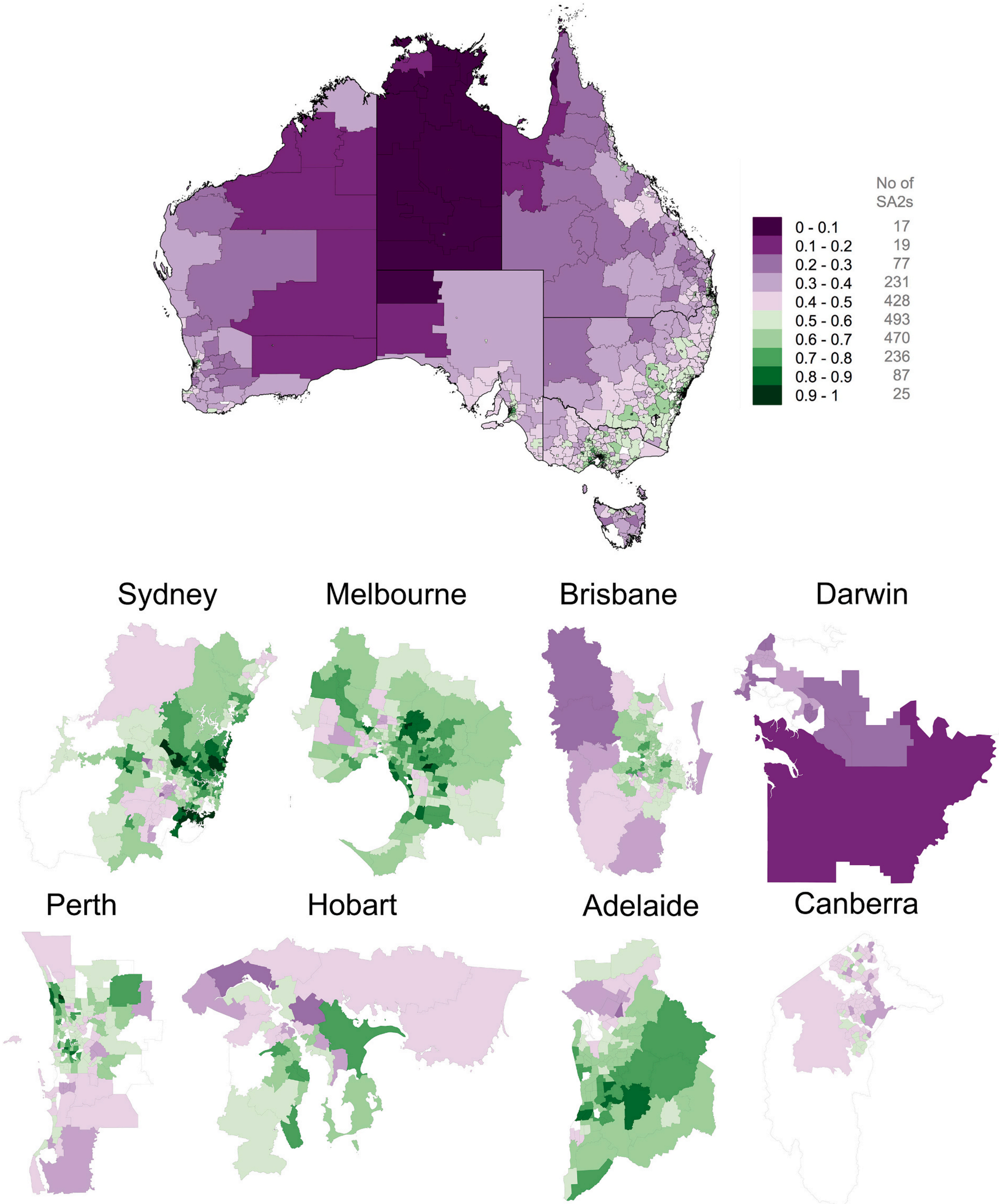

Fig. 2. Capacity for disaster resilience in Australia, assessed using the Australian Disaster Resilience Index. The index ranges from 0 to 1, where 1 is higher capacity for disaster resilience. Details of the greater capital city areas are expanded underneath the national map. Modified from Ref. [36].

the lack of integration or oversight in planning systems is not limited to remote areas.

The community capital theme represents the contribution of community cohesion and connectedness to disaster resilience. Areas of high community capital are distributed through the eastern, southern and south western periphery of Australia (Fig. 6e). Areas of high or moderate community capital occur in all remoteness classes (Fig. 7e). Areas of low community capital are predominant in very remote areas, but also occurs in the other remoteness classes (Fig. 7e).

The information access theme represents the potential for communities to engage with natural hazard information. Most of regional and remote Australia is associated with low information access (Fig. 6f). High information access tends to be concentrated into metropolitan areas (Fig. 7f).

The social and community engagement theme of disaster resilience represents the skills and characteristics of communities that support learning and transformation in the face of complex change. Areas of moderate to high social and community engagement are generally

Table 3
Population and land area associated with low, moderate, and high capacity for disaster resilience in Australia. Population was computed using ABS Estimate Resident Population as at June 30, 2015. Land area excludes SA2s not used in the analysis.

Parameter	Capacity for disaster resilience		
	Low (<25th percentile)	Moderate (25th-75th percentile)	High (>75th percentile)
Index values	0–0.4461	0.4462–0.6598	0.6599–1
Number of SA2s	521	1042	521
Population in component SA2s	3,842,568	12,323,025	7,638,030
Percentage of total population	16.1	51.8	32.1
Land area of component SA2s (km^2)	7,146,933	467,381	30,448
Percentage of total land area	93.5	6.1	0.4

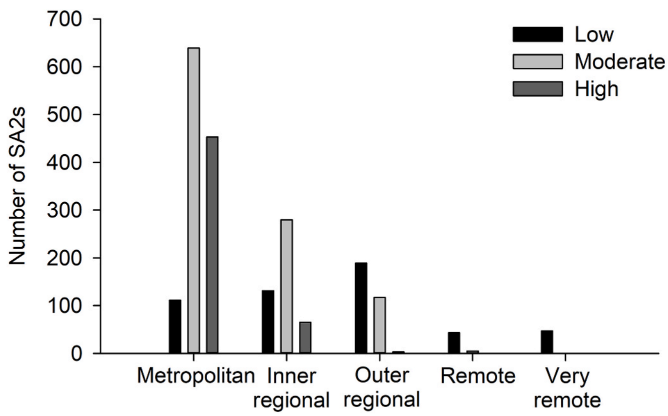

Fig. 3. Occurrence of SA2s with high, moderate and low capacity for disaster resilience in metropolitan, inner regional, outer regional, remote and very remote areas of Australia. The range of index values associated with high, moderate and low capacity is shown in Table 3.

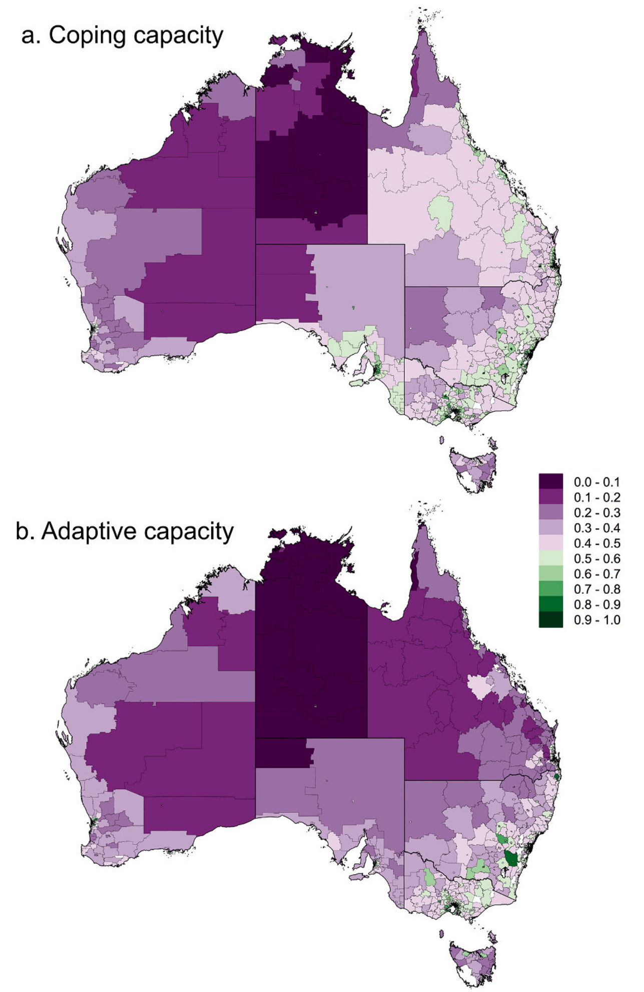

Fig. 4. Coping (a) and adaptive capacity (b) in Australia, assessed using the Australian Disaster Resilience Index. The index ranges from 0 to 1, where 1 is higher coping or adaptive capacity. Modified from Ref. [36].

concentrated along the more populous coastal areas and around major cites (Fig. 6g). Most metropolitan areas have moderate to high social and community engagement, although moderate social and community engagement is also associated with SA2s across all remoteness classes (Fig. 7g). Very remote and remote SA2s are generally associated with lower social and community engagement (Fig. 7g).

The governance and leadership theme represents the contribution that organisational adaptive and transformational capacity makes to disaster resilience. Areas of moderate to high governance and leadership capacity are concentrated in the south east of Australia (Fig. 6h). Most metropolitan areas have high or moderate governance and leadership capacity (Fig. 7h). Remote and very remote areas are generally associated with low governance and leadership capacity.

5. Discussion

Projected losses from natural hazards and the influence of climate change on the severity and frequency of extreme weather events have impelled governments worldwide to respond to the risks of natural hazards and strengthen disaster resilience as a protective factor. Systems of social, economic, and institutional factors generate inherent capacities of communities to absorb external shocks and to adapt and transform through periods of change. Top-down indices of disaster resilience at large scales reveal the occurrence and level of these inherent capacities of systems, and the spatial pattern of disaster resilience reveals their geography. This assessment of disaster resilience using the Australian

Table 4
Population (and percentage of total population) associated with combinations of low, moderate, and high coping and adaptive capacity in Australia. Population was computed using ABS Estimate Resident Population as at June 30, 2015.

		Coping capacity		
		Low (<25th percentile) 0–0.3945	Moderate (25th-75th percentile) 0.3946–0.6311	High (>75th percentile) 0.6312–1
Adaptive capacity	Low (<25th percentile) 0–0.3945	1,653,084 (6.9%)	2,184,525 (9.2%)	376,507 (1.6%)
	Moderate (25th-75th percentile) 0.3946–0.6311	1,863,726 (7.8%)	6,404,662 (26.9%)	3,194,350 (13.4%)
	High (>75th percentile) 0.6312–1	530,303 (2.2%)	4,482,181 (18.8%)	3,114,285 (13.1%)

Disaster Resilience Index showed that the distribution of disaster resilience in Australia is not uniform. There is a strong geographic signal of remoteness associated with the capacity for disaster resilience. Outer regional, remote and very remote areas were generally associated with low capacity for disaster resilience and low coping and adaptive capacity while inner regional and metropolitan areas were generally associated with high or moderate capacity for disaster resilience and

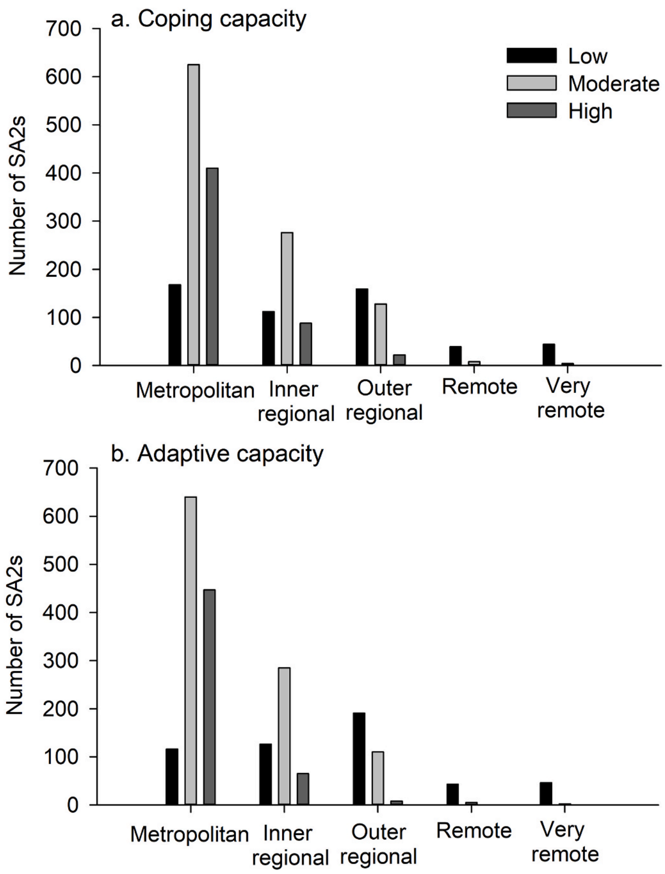

Fig. 5. Occurrence of SA2s with high, moderate and low coping capacity (a) and adaptive capacity (b) in metropolitan, inner regional, outer regional, remote and very remote areas of Australia. The range of index values associated with high, moderate and low coping and adaptive capacity is shown in Table 4.

high or moderate coping and adaptive capacity. Areas of low capacity for disaster resilience make up 93.5% of Australia's land area because these outer regional, remote and very remote SA2s are large in area, and have low population densities. In contrast, areas of high capacity for disaster resilience make up only 0.4% of Australia's land area because these SA2s are frequently metropolitan, are small in area, and have high population densities. Thus, population and land area interact to influence a non-uniform capacity for disaster resilience.

Regional areas of Australia experience inequalities in education [51], health [52,53], employment [54], income [55], and digital access [56] in comparison to metropolitan areas. Deficits in service provision and inability to attract workers to regional areas also contribute to inequality [57]. The Australian Disaster Resilience Index shows that inequality in disaster resilience is also an outcome for regional and remote Australia. Regional areas are less likely than metropolitan areas to have the capacities to absorb external shocks and to adapt and transform through periods of change. Lower capacity in regional areas is most prominent in information access and economic capital, however other themes such as community capital contribute an enhanced capacity for disaster resilience. This is commensurate with studies showing that social connectedness and capital is enhanced in regional areas and is an important contributor to disaster preparation and recovery [58,59]. On balance, regional and remote areas face barriers to disaster resilience that are generated by policy, economic, infrastructure, and social settings that privilege service delivery and economic capital to populated metropolitan areas. Improving disaster resilience will require long-term changes to structural settings to equalise the economic, service access, and social factors that contribute to lower capacity for disaster resilience in rural and regional Australia. It is unlikely that strategic intent for disaster risk reduction or disaster resilience (e.g. Ref. [60]) can be realised in Australia without first addressing the place-based differences in capacity for disaster resilience observed between rural/regional and metropolitan areas.

The association in Australia between disaster resilience and remoteness has significant implications for the planning and resourcing of disaster resilience activities. The emergence of a resilience perspective in global disaster risk reduction strategy generally expects that individuals, communities, governments, and industry will coordinate to reduce the risks of disasters and limit the social and economic impacts [15,60,61]. Broad strategic statements about disaster resilience within a shared responsibility model often acknowledge the desirable attributes of disaster resilience that can be contributed by government, community, and industry sectors. The Australian Disaster Resilience Index shows that the capacity to develop and maintain the desirable attributes of disaster resilience is not uniform throughout Australia. While remoteness contributes substantially to the capacity for disaster resilience, a mosaic distribution of low and high capacity for disaster resilience in highly populated inner regional and metropolitan areas also poses challenges for disaster resilience policy. Strategic intent to share the responsibility for disaster resilience can benefit from an understanding of the distribution of capacity across jurisdictions, so that policies and programmes can be aligned to areas of greatest need geographically.

The results of the Australian Disaster Resilience Index highlight how factors may represent a barrier to, or an enabler of, disaster resilience in different places. Combinations of high and low coping and adaptive capacity show where the use of available resources for coping with adverse events (coping capacity) and the ability to solve complex problems and make complex changes (adaptive capacity) is enhanced or may need to be supported in order to achieve strategic intent for disaster resilience or risk reduction. For example, adaptive capacity is generally higher in metropolitan areas, suggesting that the uptake of reforms and changes to support disaster resilience may need to be supported by different programs and policies in metropolitan versus regional areas. Combinations of the eight themes assessed in the index identify the mix of capacities that form enablers and barriers to disaster resilience. For example, a community disaster resilience strategy might aim to foster connected communities that work together in preparing for and responding to natural hazard events. The Australian Disaster Resilience Index shows that community capital and social cohesion (the community capital theme) may form barriers to this strategic intent in some metropolitan areas, but is likely to support strategic intent in regional and remote areas. A community disaster resilience strategy might aim to foster resilience through financial forward planning, productive and diverse economies, or insurance. Access to wealth and economic capital (the economic capital theme) may form a barrier to this strategic intent in some regional and remote areas, but is likely to support strategic intent in metropolitan areas. Understanding the occurrence and distribution of enablers and barriers can improve the design and expectations of disaster resilience investments and programmes by communities, institutions and industry.

As the notion of disaster resilience becomes increasingly common in public policy settings, critiques of disaster resilience recognize the potential for multiple, often undesirable, applications of the concept. Normative uses of disaster resilience in public policy have been linked to neoliberal ideology, with a strong focus on individualism, self-sufficiency, and market-centric approaches [62–66]. Such uses of disaster resilience in public policy push responsibility for being "resilient subjects" onto individuals [67]. Normative disaster resilience also fails to recognize that the processes which shape resilience operate primarily at the scale of capitalist social relations, and neglects the political, social and power issues at stake in the causal process inherent in putting people at risk [65,68,69]. Thus, disaster resilience is shaped by the social, economic, and institutional characteristics of places, the susceptibility of various places to harm, and the ability of systems to

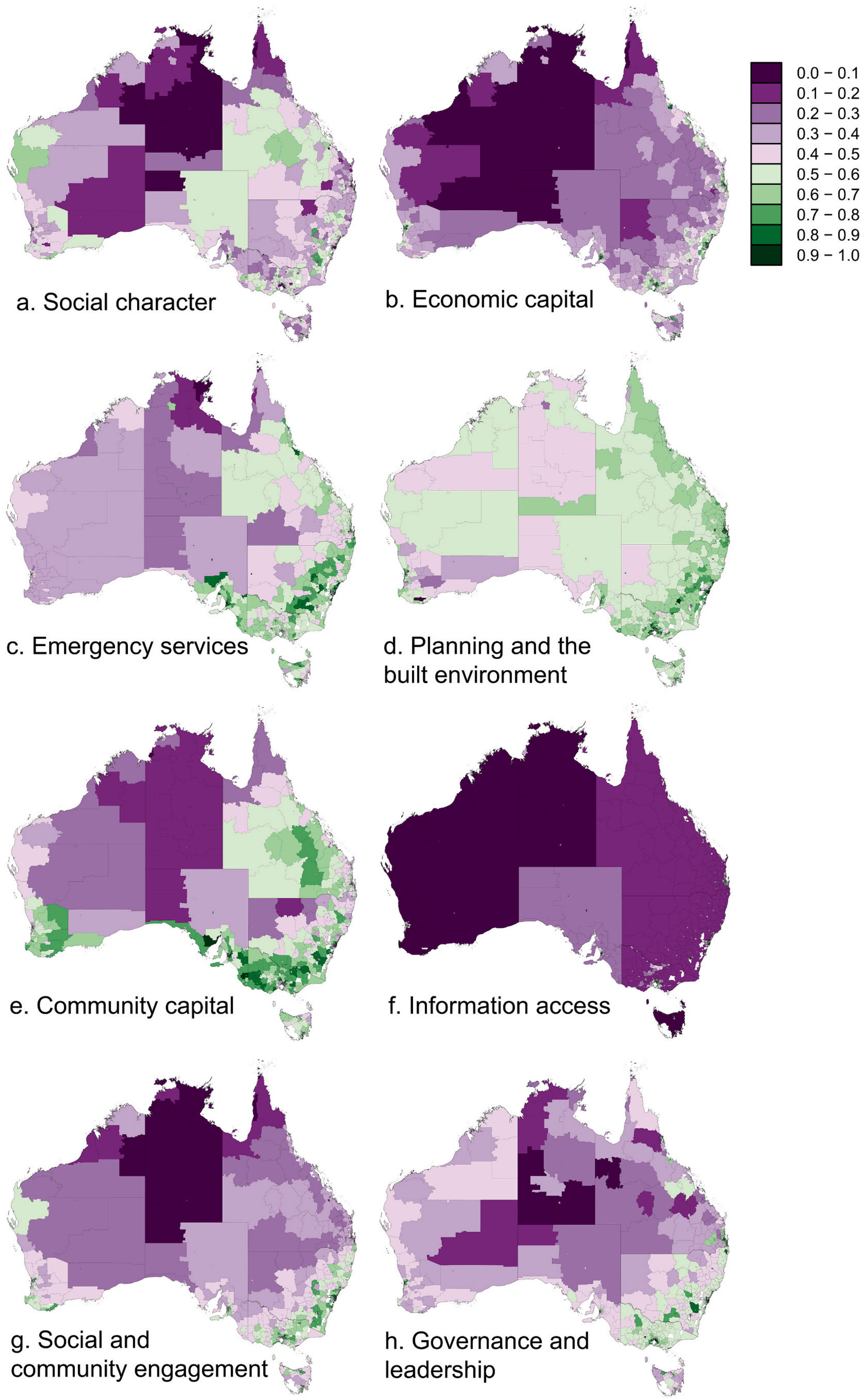

Fig. 6. Themes of disaster resilience in Australia (a–h), assessed using the Australian Disaster Resilience Index. The index ranges from 0 to 1, where 1 is higher capacity for that disaster resilience theme. Modified from Ref. [36].

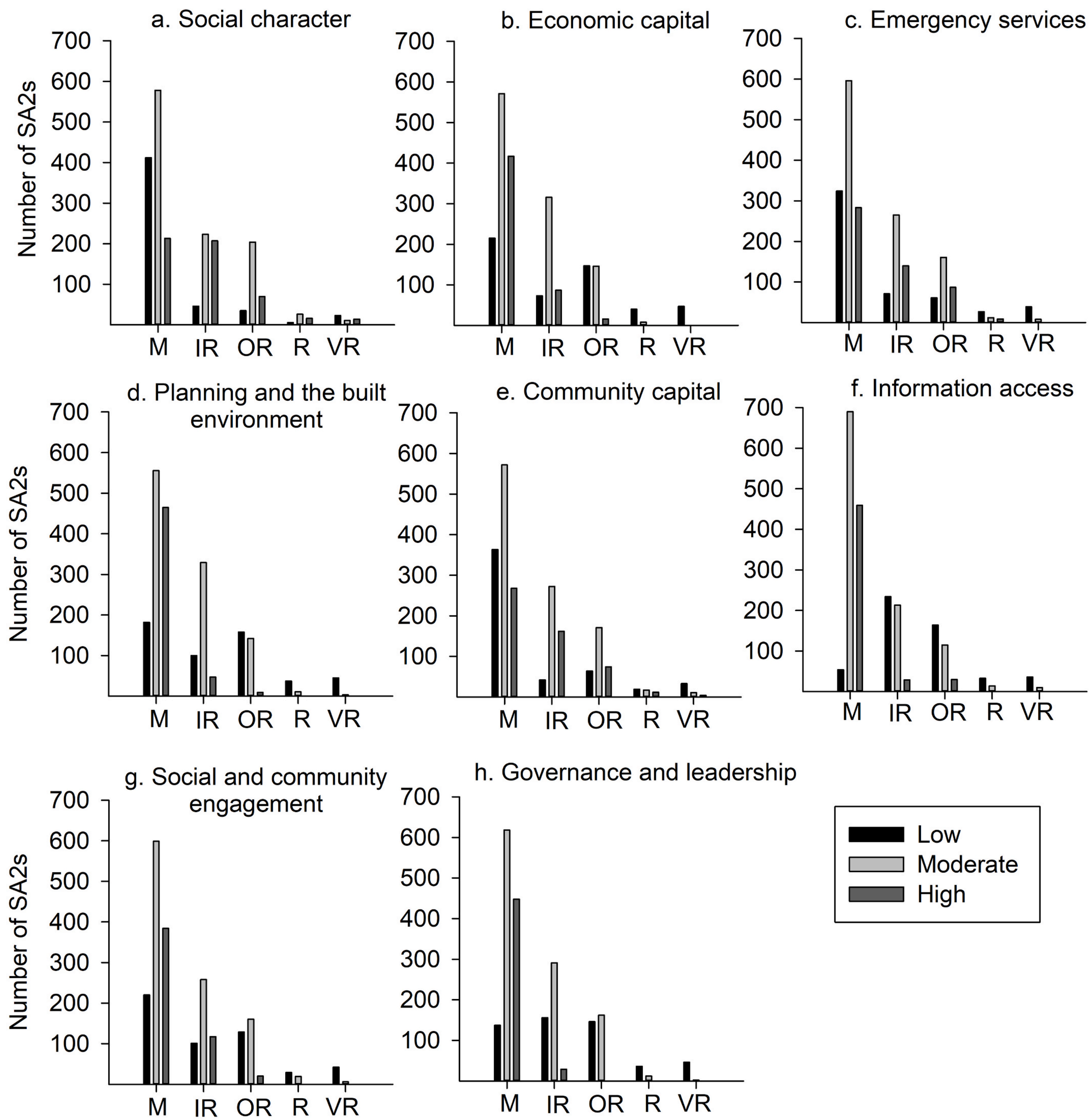

Fig. 7. Occurrence of SA2s with high, moderate and low values of capacity for each theme (a–h) in metropolitan (M), inner regional (IR), outer regional (OR), remote (R) and very remote (VR) areas of Australia. The range of index values associated with low, moderate and high capacity for each theme is set by the <25th percentile (low), 50th – 75th percentile (moderate), and >75th percentile (high) of the theme index values for all 2084 SA2s.

respond and adapt [70]. The non-uniform distribution of disaster resilience across Australia arises from socio-political processes that are place-based and sometimes, exogenous to communities. Exogenous socio-political factors such as planning policy, economic policy, or service distribution decisions are often invisible to a "resilient subject" who is participating to enhance their household or community disaster resilience within the bounds of their influence and ability. The strategic intent of disaster risk reduction and disaster resilience is potentially set for failure without recognition that systemic risk and the capacity of communities to cope with and adapt to natural hazard events is generated by a complex interplay of social, economic, institutional, and environmental trade-offs by powered actors. It is the decisions made by the powered actors that improve or reduce risk and enhance disaster resilience [71]. The Australian Disaster Resilience Index revealed a baseline distribution of disaster resilience in Australia that can be used as a decision support tool for strategic actions to address the systemic risk that sits around individuals and to enhance the capacity of communities to cope with and adapt to future natural hazard events.

5.1. *Learnings and challenges for disaster resilience index development*

Cutter ([9]; p.743) described the global landscape of disaster resilience indicators as being “just as diverse as the systems, communities or disasters that are studied”. Indices are regularly used to assess the status of disaster resilience at local, regional, and national scales. The elements used in a disaster resilience index reflect the purpose, conceptual model, scale, and location of an assessment [23]. Adaptive capacity was included in the Australian Disaster Resilience Index to assess the attributes that support anticipatory adjustment to unpredictable change and unforeseeable problems, such as that associated with natural hazards [72–74]. The assessment of adaptive capacity often showed a different geographic pattern to coping capacity across Australia, suggesting that the capacities for anticipatory adjustment to change are largely concentrated in metropolitan areas. However, substantial challenges remain for the adoption of adaptive capacity as a new element of disaster resilience assessment. Governance, innovation and learning potential are key attributes of adaptive capacity [72] but there was limited availability of relevant indicators at a national scale. Organisations do not often assess and report leadership performance, innovation practice or governance strategy: where these are reported they are organisation specific or geographically limited. Within these limitations, the Australian Disaster Resilience Index used measures of learning, leadership, and research capacity within the emergency services sector and developed a governance, policy, and leadership score (see Ref. [38]) to assess adaptive capacity. Improvements in collecting and reporting data associated with organisational governance, innovation, and flexibility will improve the contribution of adaptive capacity within national-scale indices. It is important to persist with the development of indicators of adaptive capacity for disaster resilience because of the geographic relationships between risk, vulnerability and resilience and the power of different actors to adapt to change [75].

The Australian Disaster Resilience Index was co-produced with stakeholders from the Australian emergency services sector. Throughout the process of bringing together the theory of resilience, contemporary disaster resilience index design, and the applicability of the index to agencies one concept was often at the forefront of discussions: the difference between the capacity for disaster resilience and actual (directly observed) resilience within communities. The application of a capacities approach in a national scale index is essentially an assessment of relative resilience (sensu [26]), showing the range and distribution of capacities across Australia. Practitioners in the fire and emergency services or local government sectors may work directly with communities, focusing on enhancing disaster resilience through programs of awareness, preparation, and risk reduction. Practitioners needed time to learn about, think through, and resolve the pattern of disaster resilience showing in the broader system with the patterns of individual or neighbourhood disaster resilience they observe and instil through their programmatic activities. A relative and nationally standardised measure of disaster resilience is important for state and national-level policy development and strategic planning. While the Australian Disaster Resilience Index is not designed to assess the resilience of individuals, the meaning of an exogenous system of disaster resilience that is often beyond the control of an individual can be difficult to communicate in settings focused on behaviour change or disaster preparation. Our experiences in developing the Australian Disaster Resilience Index suggest that an integrative framework is needed to communicate the principles of a disaster resilience assessment to government, non-government, and community stakeholders. Such a framework resolves the notions of capacity for resilience versus observed resilience following any one event, identifies what types of index designs and approaches are valid (e.g. empirical indices versus participatory self-assessments) and critiques the strengths and limitations of each in relation to practitioner needs. Continuing research on the validation of top-down indices in relation to disaster events (e.g. Ref. [27]) would also assist to resolve the conceptual and empirical relationships between capacities for resilience and observed resilience and the bounds of measures associated with each.

An all-hazards approach is common to many disaster resilience indices. Such indices consider resilience as a property of absorbing and adapting to the shocks and stresses of natural hazard events and assume that the same generalised disaster resilience attributes are protective for all natural hazard types (e.g. Ref. [19]). In contrast, other indices assess disaster resilience in relation to a specific hazard type, and include measures of both resilience and risk (e.g. Ref. [76]). The Australian Disaster Resilience Index applied an all hazards approach and assumed that the attributes of disaster resilience act in similar ways for all types of natural hazards. Further research is needed to overlay the resilience index with risk mapping to determine where intersections of risk and resilience may create areas for policy or programmatic attention. The natural hazard profile of Australia is well-defined, with cyclonic activity confined to Northern Australia and patchy but significant areas of high seismic risk throughout the continent. Bushfire, floods, and storms are more geographically widespread, but localised areas of higher risk, such as on floodplains, do occur. Identification of areas of low disaster resilience, coping capacity, or adaptive capacity that intersect with areas of high risk for a specific hazard type may necessitate different types of mitigation programs than areas with high disaster resilience, coping capacity or adaptive capacity.

6. Conclusion

Disaster resilience is a well-founded and relatable concept that has meaning for individuals, communities, governments, organisations and industries. Foundational resilience concepts of absorbing shocks and stresses, adapting to change, and learning and transforming have been operationalised into disaster resilience policy and programs worldwide. Disaster resilience indices support policy and programs by measuring or assessing the status of disaster resilience, often as a first step to formulating changes that improve or enhance disaster resilience [9,77]. The Australian Disaster Resilience Index assessed disaster resilience at a national scale as a system of coping and adaptive capacities. The assessment revealed a geography of disaster resilience strongly influenced by remoteness, whereby communities in regional and remote Australia were generally characterised by lower disaster resilience, coping capacity, and adaptive capacity. Created by a complex system of social, economic, and institutional factors, the non-uniform distribution of capacities for disaster resilience creates policy challenges that intersect equity, political ideology, social values, and investment decisions. While the geography of remoteness has always been a challenge for public policy in Australia at all levels of government, disaster resilience adds to a list of documented areas in which communities in regional and remote areas experience poorer outcomes than metropolitan communities. Recently this has been termed the postcode lottery, but to attribute poorer outcomes to chance is misleading. Poor outcomes in disaster resilience, as with education, health, and employment, are the result of public policy and private investment decisions, made in space and time by powered actors. With the effects of climate change predicted to influence the magnitude and frequency of most types of natural hazards, the way that public policy decisions enhance or reduce disaster resilience is coming into greater focus [1]. Large-scale assessments of disaster resilience using indices are an important tool for summarising the social, economic, and institutional system of disaster resilience and for examining how the capacities created by the system are distributed geographically.

Data availability

The Australian Disaster Resilience Index is available at www.adri.bnhcrc.com.au.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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