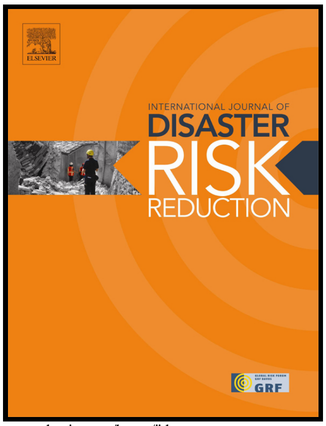

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PII: S2212-4209(15)30014-5
DOI: http://dx.doi.org/10.1016/j.ijdrr.2015.05.009
Reference: IJDRR238

To appear in: *International Journal of Disaster Risk Reduction*

Received date: 5 January 2015
Revised date: 25 May 2015
Accepted date: 29 May 2015

Cite this article as: Tim Davies, Sarah Beavan, David Conradson, Alex Densmore, JC Gaillard, David Johnston, Dave Milledge, Katie Oven, Dave Petley, Jonathan Rigg, Tom Robinson, Nick Rosser and Tom Wilson, Towards disaster resilience: A scenario-based approach to co-producing and integrating hazard and risk knowledge, *International Journal of Disaster Risk Reduction,* http://dx.doi.org/10.1016/j.ijdrr.2015.05.009

Perspective

TOWARDS DISASTER RESILIENCE: A SCENARIO-BASED APPROACH TO CO-PRODUCING AND INTEGRATING HAZARD AND RISK KNOWLEDGE

Tim Davies[1,2]*, Sarah Beavan[1], David Conradson[1], Alex Densmore[2], JC Gaillard[3], David Johnston[4], Dave Milledge[2], Katie Oven[2], Dave Petley[5], Jonathan Rigg[6], Tom Robinson[1], Nick Rosser[2], Tom Wilson[1]

Abstract

Quantitative risk assessment and risk management processes are critically examined in the context of their applicability to the statistically infrequent and sometimes unforeseen events that trigger major disasters. While of value when applied at regional or larger scales by governments and insurance companies, these processes do not provide a rational basis for reducing the impacts of major disasters at the local (community) level because in any given locality disaster events occur too infrequently for their future occurrence in a realistic timeframe to be accurately predicted by statistics. Given that regional and national strategies for disaster reduction cannot be effective without effective local disaster reduction measures, this is a significant problem. Instead, we suggest that communities, local government officials, civil society organisations and scientists could usefully form teams to co-develop local hazard event and effects scenarios, around which the teams can then develop realistic long-term plans for building local resilience. These plans may also be of value in reducing the impacts of other disasters, and are likely to have the additional benefits of improving science development, relevance and uptake, and of enhancing communication between scientists and the public.

[1]University of Canterbury, Private Bag 4800 Christchurch 8140, New Zealand
[2]Durham University, Durham, UK
[3]The University of Auckland, Auckland, New Zealand
[4]GNS Science Ltd, Lower Hutt, New Zealand
[5]University of East Anglia, Norwich, UK
[6]National University of Singapore, Singapore
*Corresponding author. Email tim.davies@canterbury.ac.nz; ph +64 3 3642987

KEYWORDS: disaster risk quantification: risk management: community resilience: event and effects scenarios: co-production of knowledge.

1. Introduction

Current disaster reduction strategies are not working as well as anticipated (United Nations, 2011; Wisner at al., 2012); the societal impact of major naturally-triggered disasters continues to increase with time, although the number of fatalities appears to be falling (United Nations, 2009). The increasing impacts of natural events in part reflect increasingly vulnerable and growing populations, as well as the vulnerability of expanding infrastructure and investments, so that there is ever more to lose in any given disaster. The increasing impact of natural events may also reflect changes in earth system processes, due for example to climate change. Nevertheless, we suggest that more can be done to reduce the impacts of disasters at the local (community) level, by taking a novel approach to describing what we can know about future disasters. In particular, we suggest that current disaster *risk* reduction (DRR) strategies are not fully effective in anticipating the *impacts* of disasters, and thus in allowing those potentially affected to take action to reduce these impacts.

The present article is intended as a multi-disciplinary commentary, in the hope that it engages a multi-disciplinary audience in the topics of local-level disaster reduction and resilience building. Our aim is to facilitate productive dialogue; we present what we see as key principles in a form that is as accessible as possible, to as many disciplines as possible, in order to encourage inter-disciplinary debate. In taking this approach we acknowledge that many of the topics we touch on have deep background literatures, and may in due course require much fuller treatment than we provide here. We begin by outlining some of the problems, both theoretical and practical, with current disaster reduction strategies. This leads to the suggestion that local event and effects scenarios, developed in collaboration with communities, could support local-level planning, complementing the use of conventional probabilistically-based risk analyses at regional and larger spatial scales by, for example, governments and insurance companies. We also suggest that community/local government/civil society organisations/scientist teams can work to integrate community knowledge with science and 'expert' knowledge (or what Lane et al. (2011) call non-certified and certified expertise), so as to develop these disaster scenarios together. We argue that these co-produced scenarios, if generated with an awareness of the relevant policy and governance contexts, can serve as a useful consensual basis for developing more effective resilience strategies over time-scales of societal interest.

2. Definitions

"Community" is used widely in disaster risk reduction circles as a focus for local-level planning and bottom-up engagement but the concept is complex and contested. Cannon (2014) interrogates the concept of community in the context of grassroots work and the role of community level work in DRR, specifically arguing that there is no such thing as community; it is simply a convenient entry point for research, policy and practice. Whilst acknowledging this critique and the internal divisions and associated power dynamics that can exist, we use the term here to represent a varied group of people, spatially situated, who are – to some extent – socially and economically interlinked; and exposed to a disaster or disasters, both by virtue of their location in relation to particular hazards, and also as a result of development and increasing social inequality. We are particularly interested in communities from which a desire to increase their ability to plan for, cope with, and redevelop following a major disaster has been expressed. We recognise that every community is linked to and part of wider society, and that this two-way linkage helps shape community aspirations, behaviour and wellbeing.

"Resilience" is notoriously difficult to define in an operational sense, even if intuitively less difficult to conceptualise in general terms (Alexander, 2013). For present purposes, we adopt the following definition of disaster resilience: '*the ability of individuals, communities and states and their institutions to absorb and recover from shocks, whilst positively adapting and transforming their structures and means for living in the face of long-term changes and uncertainty*' (OECD, 2013b, 1). A current definition of disaster risk reduction (DRR) is *'the concept and practice of* ***reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters****, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events*" (our emphasis; http://www.unisdr.org/we/inform/terminology).

The essential purpose of DRR is to reduce the impacts of future disasters on society. The measures needed to achieve this are, by implication, measures that increase the resilience of society to disasters. In this commentary, we focus on rare and severe disaster events that are rapid in their onset e.g. earthquakes, landslide and floods. However in doing so, we recognise that building resilience to such events cannot be tackled in isolation from the more frequent "everyday" hazards that impact people's lives and livelihoods. We also acknowledge that people may be constrained in terms of the actions that they can and are willing to take due to poverty and poor health, among other factors. Our focus here is on often known but rare events whose nature and time of occurrence are unpredictable, as these tend to be overlooked by comparison with the more frequent events that are more to the fore in public consciousness (and can, as we show, be used to develop awareness of more damaging events). The rare events are however very catastrophic when (inevitably) they do occur; our intent is to show that their effects can nevertheless be reduced, albeit not by using conventional disaster risk reduction procedures alone.

On this basis, we now consider some of the impediments to improving the resilience of communities and the societies of which they are a part.

3. Problems

Disaster reduction has advanced considerably since the late 20th century. It has become more rigorously defined and organised, centring around risk management (UNISDR, 2009); it has also become more multidisciplinary and integrative (Twigg, 2004; Wisner et al., 2012). We have, for example, seen a recent surge of interest in incorporating science into DRR (e.g. Southgate et al., 2013; DFID, 2012; Duncan et al., 2014; Aitsi-Selmi et al., 2015). When compared with the parallel area of environmental management, however, there remain a number of issues that impede progress in building the resilience of communities to disasters. Lavell and Maskrey (2014) identify many such obstacles, but two of the most important for the present argument are lack of political will and very limited decentralization and devolution of resources (financial and technical) to local government units to support local level disaster risk reduction .

We see, in addition, three more fundamental difficulties in the conventional methodologies of disaster reduction:

1. Limited and ineffective integration of science into disaster reduction planning, policy and practice.
2. Lack of effective community participation in developing resilience to major disasters.
3. Overemphasis on probabilistically-based hazard/risk assessment and management in the context of disasters.

These difficulties are expanded on in turn:

1. The natural and social sciences provide information on the behaviour of the natural processes of the planet, how they impact society, and how society responds to such impacts. We contend that these insights are as yet relatively poorly utilised in disaster reduction, for a number of reasons that include lack of or poor communication among the broad range of involved scientists, practitioners, policy-makers and lay persons. This limits the production and uptake of useful and useable science, with the result that planning and policy tend to be driven to a large extent by short-term economic and political concerns and priorities.
2. In a specific locality, resilience-building aims to reduce the effects of future disasters on the people who live, work or play there, whether permanently or temporarily. Yet these

interest groups are rarely closely involved in the development of disaster reduction measures. Although there is often some degree of consultation with representatives of local interest groups, or even public meetings and focus groups, in many cases local community knowledge of societal and natural processes is neither sought nor incorporated into the disaster reduction planning process. When community participation is sought, it is not uncommon for the debate to be captured by more influential or powerful stakeholders (Cooke and Kothari, 2001; Mansuri and Rao, 2013; Mosse, 2005).

3. Risk management is currently the common basis for disaster reduction worldwide; it depends on anticipation of future events able to trigger disasters, and their quantification and analysis (usually in terms of magnitude and probability). However there are (at least) five fundamental problems that limit the effectiveness of this approach for reducing disaster damage in a specified locality:

   a. Probabilistically-based event predictions for a specific locality are intrinsically unreliable even for known and well quantified disaster events because, *by definition*, potentially disastrous events occur only a small number of times at a given location in any realistic planning time-frame, and probabilistic predictions of small samples have an intrinsically high degree of unreliability (Davies, 2015). In other words, when only a very small number of disaster events will occur in a realistic planning time-frame, it is extremely unlikely that their occurrence will match the probability of their occurrence. A further difficulty – albeit one that is less fundamental and more able to be remedied – is the fact that statistics for most disaster events are poorly-defined. Probabilistically-based risk analysis is essential and useful to the disaster insurance industry, in part because this industry spreads risk over large spatial areas and temporal periods, so that the number of disaster events considered is always high. It is also useful for governments responsible for disaster reduction across large areas of nations or regions. For local communities, however, it is of far less utility than conventionally assumed. Despite this, probability-based risk analysis is often the default mechanism for risk management, even at local scales (e.g., Papathhoma-Kohle et al., 2015; Anderson et al., 2014)

b. The impacts of large natural events on society result from the interaction of two complex dynamic systems: Earth processes and societal processes. Knowledge of the behaviour of complex systems suggests that the major hazard events that impact society are intrinsically unpredictable in location, timing and intensity (Kagan, 1997; Park et al, 2013; Sornette, 2002; 2009), and thus the societal consequences are likely to be unexpected when they occur. In addition, from (a) above, only the risks associated with smaller and more frequent events can be quantified adequately at the community scale. Risk management by definition requires risks to be known and therefore expected, and also adequately quantified, so cannot be reliably applied to disaster situations. Furthermore, the complex interactions between physical, ecological and human systems have to be seen and understood in the context of a rapidly transforming society. Social vulnerability, on the other hand, although also complex, is grounded in everyday life and reflects the structure of society (Wisner et al., 2004). Ultimately, integrating both the unpredictable dimension of natural hazards and the everyday nature of vulnerability is necessary and constitutes one of the key challenges facing us (Berkes, 2007; Folke, 2006; Wisner, 1995; Wisner et al., 2012).

c. The use of quantified risks to calculate cost-benefit ratios (or other utility optimisation criteria) leads to extremely imprecise results. These procedures involve calculating the differences between large and imprecise numbers (e.g. unmitigated annual damage and mitigated annual damage), the result of which is, inevitably, a much smaller and very much less precise number (in this case, gross benefit). When the cost of mitigation measures (also necessarily imprecise) is subtracted from gross benefit to yield net benefit, the imprecision increases even more (see text box).

d. Assigning an identified, large future event a very low probability usually means that it is assumed to be of lesser priority than more frequent - and therefore more "urgent" - smaller (but still large) events. Thus, when the large event does (inevitably) occur, it is in most cases unexpected because society – including local communities - has decided to ignore it or delay its consideration; in this context its low probability effectively becomes zero probability.

TEXT BOX: Sensitivity of cost-benefit analysis to small errors:

Unmitigated average annual damage cost: \$1,000,000 ± 10% = \$900,000 - \$1,100,000

Mitigated average annual damage cost: \$600,000 ± 10% = \$540,000 - \$660,000

Gross average annual benefit: \$560,000 – \$240,000 (\$400,000 ± \$160,000 or \$400,000 ± 40%)

Annual average mitigation cost: \$300,000 ± 5% = \$285,000 - \$315,000

Net average annual benefit: \$275,000 - \$-75,000 (\$100,000 ± \$175,000 or \$100,000 ± 175%)

Thus the net average annual return on investment, neglecting errors, of \$100,000/\$300,000 = 33%, is in fact anywhere between 92% and -25%. With increasing errors, the precision of the net average annual benefit deteriorates rapidly. While utility optimisation is only one of a suite of criteria relevant to disaster reduction decision-making, it often has considerable influence on decision-making because it is quantitative.

e. The lack of effective local-scale disaster reduction caused by the limitations of risk management in turn means that efforts to reduce larger-scale (regional, national and global) disaster impacts (for example by optimising the availability of emergency resources and advice) cannot be fully effective, although the probabilistic methodology can in principle be applied at the larger scales.

4. A way forward

From the above, it is evident that alternative strategies are required that enable communities to plan for large, poorly-quantified or unexpected events that occur rarely (but will occur, and can occur at any time), and to improve the uptake, relevance and completeness of science for local level resilience planning (Paton and Johnston, 2001). These alternative strategies – whatever they are – are required to complement the conventional risk-based disaster reduction strategies commonly in use.

We outline below how these requirements can be met by using sets of scenarios, co-developed by communities, civil society organisations and local government officials working closely in teams with scientists (with a range of disciplinary expertises), to address those situations where risk management-based solutions are inadequate for the reasons set out above. These scenario sets describe the effects of large natural events on a community[3], and provide a basis for further work by community-civil society-scientist-local government teams to devise strategies for reducing the impacts of these effects, thus increasing resilience. Finally, long-term partnerships between the different stakeholder groups are needed to build trust and to develop a more in-depth understanding of the social and natural systems and their changing vulnerability over time, and to maintain and improve resilience as both communities and natural systems – and our understanding of them – alter over time.

This suggestion is a substantial departure from current practice. Its implementation will require local governments, civil society organisations, scientists and communities to learn how to work equitably and constructively with each other. These kinds of collaborations are presently being explored in a

[3] We mention here that these scenarios are in many ways similar to those commonly used in existing community-based DRR activities, although rarely for large events because of the lack of collaboration with scientists.

locality in New Zealand and as part of the Earthquakes without Frontiers project in Central and South Asia (http://ewf.nerc.ac.uk) by a number of authors of the present Commentary. What is really needed, however, is a set of simple methodologies that can be adapted for different contexts to guide the co-production of scenarios. Examples geared towards integrating different forms of knowledge and actions through enhanced dialogue between local and outside stakeholders have been trialled and the outcomes are encouraging in the context of expectable hazards such as floods (e.g. Lane et al. 2011; Cadag and Gaillard, 2012; Wisner et al., 2012). However, we argue that such approaches need to be developed further to move beyond conceptual framings of knowledge integration and one-off examples, and to consider how such collaborations might work in the context of less predictable hazards such as earthquakes where the role of scientific knowledge is less clear. Alongside, and informed by, this practical exploration of methodologies, work is needed to establish how these methodologies could be produced, piloted, evaluated, rolled out, monitored and revised. Within this work, there is a need to address the question of precisely who in a community should be involved (and what social sub-groups they represent), how to identify and recruit people (especially the less visible and harder to reach), and how to support those involved. Within local government and civil society, there is also a need to establish the approximate profile of the kinds of groupings required to complete the group that successfully produces scenarios together.

4.1 Scenarios

Rather than describing future disaster events primarily in terms of their magnitudes and probabilities, we suggest that information about what can happen in the most important disaster– the next one – can be better developed by communities, practitioners and policy-makers by using sets of scenarios. These scenarios describe the natural events that trigger disasters, together with anticipated consequences for other natural systems (such as the triggering of landslides and consequent river aggradation by earthquakes, e.g. Gill and Malamud, 2014). Together, they comprise the *event or hazard scenarios*. The scenario sets also describe the effects of these natural events on societal systems (the *effects or impact scenarios*). In reality the variation in event scenarios is much greater than the variation in effects scenarios: the latter are mostly injuries, deaths and damage, loss of commerce, loss of communications, and isolation, whereas the former encompass earthquake, landslide, flood, storm, snow, ice, tsunami, debris flow and other processes. Thus we suggest that effects scenarios are more useful than event scenarios, both because they are more easily foreseen, and because these are the scenarios to which a community needs to develop and respond in order to become more resilient. Co-developed by local and outside experts, the outcome is potentially better than any group could achieve on its own, or by means of consultation or communication with other groups. The event scenarios are based on known science, but crucially are informed and improved by the community's experience of natural system behaviour and knowledge of the local social, cultural, economic and political context. The effects scenarios are based on the community's knowledge of how it has been or could be affected by a particular hazard or hazards, the impact of the hazard(s) in terms of loss of life and livelihood (including the potentially uneven effects across society) and how the community wants to develop into the future e.g. the building of a new road to provide market access for the sale of cash crops. They are also informed by what science can say about future natural and human system behaviours e.g. the potential for future earthquakes and the impact of demographic change through labour migration on local level resilience (Rigg and Oven 2015). This process requires scientists to engage closely with the different members and parts of communities (including commercial and cultural interests, formal and informal governance structures, policy-makers, marginalised and vulnerable social groups, and other key stakeholders), and this in turn requires development of mutual trust among all involved (Gaillard and Mercer, 2013). This co-development process is beneficial not just because such engagement permits mutual learning, the sharing of existing knowledge and the co-production of new knowledge, but also because the knowledge that emerges is much more likely to have societal and scientific traction, *because it will be perceived as relevant by all involved* (Mercer, 2012; Wistow et al. 2015). Knowledge and understanding of hazards and their effects is not only increased, improved and integrated into resilience planning, but is also intrinsically produced, rather than being simply disseminated, so as to become common to all involved.

While it is well recognised that such initiatives should be community-owned and led to be successful, the role of government (local and national) and civil society organisations in these resilience teams is essential to unlock the political and economic resources required for local level resilience building (Maskrey 2011). As summarised by Maskrey (2011: 51), in his review of community-based disaster risk management, such government-civil society partnerships 'enable the investment of resources that are unavailable locally and increase continuity and sustainability as initiatives move from stand-alone projects and programmes to longer-term processes' (Maskrey 2011: 51).

The quality of communication within the diverse community-civil-society-scientist-local government teams is crucial to the quality of the outputs. This requires acknowledgement and specific attention, involving perhaps an experienced and independent facilitator.

4.2 Resilience planning

When a set of scenarios has been developed that the team agrees is a useful representation of what can occur when the community experiences a disaster, the next stage is to develop ways of reducing the impacts of the chosen scenarios on society, in particular in the context of how the community foresees itself changing into the future. Indeed, thinking into the future is likely to highlight some specific strategies for increasing resilience, for example, by reducing dependence on particular social arrangements, processes or behaviours that contribute to present-day vulnerability to the given scenarios. This may involve, for example, agricultural diversification; or, in extreme cases, gradual relocation of assets.

In this strategy there is an implied assumption that increased resilience to the scenario effects will result in increased resilience to the next major event to affect the community, whatever it is, and so the choice of the set of scenarios is clearly important (Alexander, 2000). By concentrating on the effects scenarios, and developing resilience to them by addressing the causes of vulnerability, there is also the possibility – albeit one that cannot be tested in advance - that societal resilience to events that differ significantly from the event scenarios will also be increased. As noted above, a powerful justification for community-chosen scenarios is that they are by definition *highly relevant to the community*; this perspective may need to be emphasised to counter external challenges that the chosen scenarios are less relevant than other scenarios.

It may also be possible to use some scenarios, based on less extreme events whose effects are known locally, as 'gateways'. These scenarios can be used as ways of building resilience to the effects of other events that the community has not yet experienced (Robledo et al., 2004). For example, a community with rich experience in dealing with the effects of frequent landslides may be able to use that experience to design arrangements or processes that will help build resilience to the effects of less frequent (but potentially much more damaging) earthquakes. Again, building scenarios for the effects of one event may help to build resilience to the effects of other events. Engagement and therefore empowerment with regard to the development of one scenario has the potential, we argue, to ripple through to other scenarios and events; this potential, however, remains to be tested, and is an avenue for future research.

As in all attempts to manage human-natural system interactions, the effects of the resilience measures developed and implemented by the community-civil society-scientist-local government teams need to be continually monitored, evaluated, reflected on and adapted as the community and its natural environment evolve. The real effect of the resilience measures adopted will only become clearly evident following a disaster event, but the effects of minor events may give some useful indications of measures that could usefully be modified. This monitoring, evaluation and reflection need to be carried out by the community-scientist-local government team, which means that this team is not a one-off project collaboration but must continue to act as a resilience advisory team for the community, as suggested by many community-based disaster risk reduction and management initiatives over the past three decades (e.g. Maskrey, 1984; Delica-Willison and Gaillard, 2012). Thus while such community-science-local government partnerships clearly have the potential to offer immediate benefits, it is also likely that these will increase over time. Ongoing joint engagement offers the best chance of maximising such benefits, and of facilitating adaptation to medium- and longer-term changes in natural and social systems. Involving communities in building scenarios for resilience will help to ensure maintenance of local focus when national policy attention turns elsewhere (Delica-Willison and Willison, 2004).

Using the information derived from the documented co-production of scenarios and resilience-building initiatives, both natural and social scientists can develop increasingly-sound scientific bases for understanding natural events and the vulnerability and resilience of society to disasters resulting from them.

It is perhaps useful here to think about where the responsibility lies for planning community resilience to future disasters. Any community is a deeply-linked component of local, regional and national society, and while its well-being is of significance at all scales, its significance is nevertheless highest locally. Thus direct responsibility for planning for future disasters lies primarily in and around the community. In some cases, however, the regional and national linkages may be so important that a disaster to the community severely affects regional and national economies, for example the devastation of an iconic but small tourist town. Here responsibility is more widely distributed. In any case, implementation of resilience strategies will often be beyond local resources, and higher-level assistance will be needed.

Finally, we acknowledge that the strategy we suggest has a number of potential drawbacks that may hinder its uptake. For example, the co-development of scenarios:

- is likely to be time-consuming, a difficulty in an age of ever tighter deadlines and planning horizons, together with fixed project durations;

- requires trust, development of which also requires above all time to know others well;
- requires considerable flexibility on all sides, which in turn requires that established positions need periodic reflection and re-examination;
- requires a community to recognise the existence of specific and unknown hazards and express a desire to address them which cannot be forced upon them;
- requires recognition from the team that this may mean focusing on more immediate concerns of the community in the first instance until trust is built and priorities are aligned; and
- requires recognition and navigation of the tensions between practical actions and research, and between practical actions and policy.

Nevertheless, this strategy does appear to offer a way to increase the relevance of disaster risk reduction to local communities, leading to genuine reduction of future disaster impacts.

5. Summary

The imprecision intrinsic to probabilistically-based risk management means that it can be applied reliably only to large numbers of potential disaster events. This means in turn that, while applicable to disaster reduction across large areas (e.g., over nations or regions by governments, and over even larger areas by insurance companies), probabilistically-based risk management cannot reliably be used as the basis for community disaster reduction – which necessarily involves a limited spatial area – over planning time scales relevant to society. This leaves a crucial gap in disaster reduction methodologies locally, and therefore also at larger scales. Here we have suggested complementing the probabilistic risk management process, which operates effectively on well-known and frequent risks, with the development of disaster event and effects scenarios as a basis for local level resilience building for poorly-known or unknown risks (in which risk management has intrinsic unreliability).

The active and ongoing process of joint learning by community-civil society -scientist-local government teams engaged in developing these scenarios, and the resulting plans for gradually reducing vulnerability, have in addition the potential to (i) achieve greater integration between community experience and formal science, (ii) produce increased understanding of the complex behaviours of natural and social systems, and (iii) advance the natural and social sciences that describe hazard events and their effects (Lane et al., 2011) in relevant and applicable directions. This, we argue, is a key to making science more 'useful, usable and used' in DRR (Boaz and Hayden, 2002) while providing communities with a basis for developing increased resilience to the next major disaster event.

6. Acknowledgements

This perspective is one outcome of a 3-day meeting of disaster scientists from Durham University, UK, the National University of Singapore and New Zealand in Singapore in June 2014, where the focus was on fostering resilience to large disasters in mountain terrain. The meeting was supported jointly by Durham University, UK, University of Canterbury, NZ, and the National University of Singapore. Tim Davies gratefully acknowledges the funding of a senior research fellowship at Durham University, supported by the Durham University Institute of Advanced Studies and the European Union, which facilitated the completion of this work. We also acknowledge with gratitude the comments of three anonymous reviewers and Ben Wisner.

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