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Knowledge sharing in interdisciplinary disaster risk management initiatives: cocreation insights and experience from New Zealand

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ABSTRACT. Decision making in complex contexts such as disaster risk management requires collaborative approaches to knowledge production. Evidence-based disaster risk management and pre-event planning relies on robust and relevant disaster risk knowledge. We report on a case study of Project AF8, a “cocreation” collaboration involving local- and central-government disaster risk management agencies and groups, critical infrastructure organizations, and scientists from six universities and Crown Research Institutes. Participant observation and interview data are used to document and analyze the processes used to generate, share, and apply multidisciplinary disaster risk knowledge. Project AF8 was conceived as a cross-jurisdictional and multiagency initiative to plan and prepare for a coordinated response across the South Island following a large magnitude earthquake along the Alpine Fault, one of New Zealand’s major natural hazard risks. Findings show that (1) practitioners at all levels operate in highly uncertain environments and therefore have specific knowledge needs at different times and for different purposes, (2) disaster risk knowledge was perceived to be most effective when scientifically credible and focused on identifying likely impacts on the capacity of communities to function, and (3) disaster risk knowledge outputs and the processes used to cocreate them were perceived to be equally important. Using cocreation to combine researcher credibility with practitioner relevancy enhanced the legitimacy of Project AF8 processes, the collective disaster risk knowledge they facilitated, and the wider project. In hindsight, a greater focus at the outset on developing a formal coproduction structure may have increased the pace of cocreation, particularly in the early phases. Future interdisciplinary disaster risk management initiatives could benefit by adopting contextually relevant aspects of this example to strengthen the science-practice interface for more effective pre-event planning and decision making.

Key Words: *coproduction of knowledge; disaster impacts; disaster risk management; hazard research; interdisciplinary; science-practice interface*

INTRODUCTION

Losses from disasters continue to rise globally with implications for human well-being and livelihoods (Cutter et al. 2015, Tanner et al. 2015). Two trends in disaster risk reduction (DRR) and resilience science are attempting to address this, with science defined as the “systematic approach to the creation of new knowledge” (Chalmers 1976, as cited in Wyborn et al. 2017:5). Both these trends align with the recommendations of the Sendai Framework for Disaster Risk Reduction (UNDRR 2015a). First, the analytical focus has shifted toward the underlying drivers of disaster risk, including hazards, vulnerability, and exposure (Fekete et al. 2014, Mechler and Bouwer 2015, Thomalla et al. 2018). Second, multidisciplinary teams that include both practitioners and scientists are increasingly being used to codesign DRR and resilience solutions (Aitsi-Selmi et al. 2016, UNDRR 2019).

Researchers can find it difficult to successfully navigate this new approach, particularly if they understand their role to be generating scientific disaster risk information to be delivered to decision makers (Doyle et al. 2015, Kete et al. 2018). To enhance strategic DRR planning the goal is not to deliver, but rather cocreate shared knowledge that is robustly scientific while also meeting decision-making needs (Aitsi-Selmi et al. 2016, Aldrich 2019, Djalante et al. 2011, Aoki 2018). Internationally, a number of multiagency and interdisciplinary earthquake resilience initiatives have emerged in the past 10 years (Table 1). Despite the significant investment in these and other initiatives, there are very few academic studies that document the cocreation and utilization of scientifically robust knowledge in these initiatives (Cvitanovic et al. 2018), particularly those that are government led.

We used an in-depth case-study analysis of Project AF8, initially a three-year disaster risk management project, to improve understanding of the cocreation processes and the resulting collective knowledge required by science-based, government-led initiatives. Project AF8 is funded, led, and administered by central and regional New Zealand government agencies. It also draws heavily from largely informal collaboration and cofunding relationships with New Zealand science communities to develop and implement scientifically robust earthquake scenario-based emergency response preparation and planning for a large-magnitude Alpine Fault rupture (Orchiston et al. 2018). The Alpine Fault is considered a major natural hazard risk for New Zealand (Orchiston et al. 2016), particularly for the predominantly rural communities and industries in the South Island. With the case study, we aimed to gain insight into the processes used to navigate the interface between science and practice, the knowledge that was cocreated in this way, and to identify challenges and best practices applicable in other national and international contexts.

Disaster risk knowledge and the science-policy-practice interface

The United Nations defines disaster risk information as the information on all dimensions of disaster risk, including hazards, exposure, vulnerability, and capacity, related to persons, communities, organizations, and countries and their assets that is required to understand disaster risk (UNDRR 2015b). Knowledge is defined for the purposes of this paper as “understanding of or information about a subject that you get by experience or study, either known by one person or by people generally” (Cambridge Dictionary, <https://dictionary.cambridge.org/dictionary/english/knowledge?q=knowledge+>). Understanding

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Table 1. Examples of large multidisciplinary disaster resilience initiatives since 2008, involving disaster risk management decision makers, scientists, and public stakeholders.

Initiative (country)	Goal	Funding amount	Status	Time line
Project AF8 (New Zealand)	Improve the response capability of regional agencies, and develop an operational plan to support the response.	NZ\$490,000 (~US\$319,800)	Active	4 years, June 2016 to June 2020
East Coast LAB (New Zealand)	Multiagency initiative to improve resilience to communities on the East Coast from off-shore natural hazards including the Hikurangi trough.	NZ\$240,000 (~US\$156,600)	Active	1 year, July 2018 to June 2019
It's Our Fault (New Zealand)	To see Wellington become a more resilient city through comprehensive study on earthquake likelihood, effects, and impacts.	~NZ\$450,000 annually (~US\$163,200)	Active	Ongoing, since 2006
Real Time Earthquake Risk Reduction (EU)	Improve preparedness for earthquake hazards by enhancing real-time risk mitigation and establishing methodologies for practitioners.	~€10.1 million (~US\$11.3 million)	Complete	3 years, September 2011 to December 2014
Increasing Resilience to Natural Hazards (UK)	To build resilience in earthquake-prone and volcanic regions by reducing risks from multiple natural hazards and increasing population resilience to high impact events.	~£8.3 million pounds (~US\$10.78 million)	Complete	8 years, 2010–2018
Science for Humanitarian Emergencies and Resilience (UK)	To improve the characterization of the hydrological controls on natural hazards thereby enabling better prediction of their occurrence and scale, with a focus on landslide risk.	~£19 million pounds (~US\$24.68 million)	Ongoing	7 years, 2015–2022
Hayward Fault Initiative (USA)	To promote risk reduction locally, by providing information on earthquake consequences and encouraging risk reduction programs.	N/A	Complete	Original in 1996, updated in 2010.
Haywired Scenario (USA)	Scenario development to advance risk analysis and inform disaster planning (preparedness, response, and recovery).	N/A	Active	Ongoing, since 2017
Great Southern California ShakeOut (USA)	Earthquake drill to increase public awareness and understanding of response.	N/A	Active	Annual, since 2008
The SZ4D Initiative (formerly Subduction Zone Observatory; USA)	Understanding the processes that underlie subduction zone hazards in four dimensions.	US\$4.9 million	Active	3 years, September 2018 to August 2021

scientifically credible disaster risk information is widely seen as the core of effective disaster risk management (Calkins 2015). Disaster risk management (DRM) is the holistic application of DRR policies and strategies to prevent new disaster risk, reduce existing disaster risk, and manage residual risk (UNDRR 2015a). Disaster risk management relies on knowledge sharing between practitioners and researchers to advance risk awareness and understanding, and facilitate DRR behaviors (DiClemente and Jackson 2017, WHO 2019). This knowledge sharing occurs as a function of the science-policy-practice interface, which Wyborn et al. (2017:5) define as “the processes and settings in which decision-makers in government, civil society and business use, misuse or reject scientific research in forming their thinking, analyses or decision-making.”

The focus of efforts to understand disaster risk has evolved over recent decades. Earlier research investigations of the physical properties of events, e.g., intensity, spatial extent, frequency, or probability, have expanded over time to include consideration of the extent and severity of impact to society, e.g., damage and disruption, and the use of mitigation and adaptation strategies to maintain and restore basic societal functions (O'Rourke et al. 2008, World Bank 2012, Simpson et al. 2014). This evolution has been informed by growing recognition of the extent to which disasters, although triggered by natural hazards, are inherently social processes (White et al. 2001).

Recognizing that disasters are highly complex, this trend places greater emphasis on understanding interdependencies between social, built, cultural, political, economic, and natural environments (O'Rourke et al. 2008, Gaillard and Mercer 2013, Komendantova et al. 2014, Guidotti et al. 2016, Paton and Buergelt 2019). In the climate change adaptation (CCA) domain it manifests in findings confirming that knowledge of disaster impacts has more influence on disaster risk policy and practice than knowledge of hazards (Wisner and Walker 2005, Schipper and Pelling 2006, Mercer 2010, Cradock-Henry et al. 2019, Leitch et al. 2019).

Recent research has highlighted different ways of understanding the processes and settings in which policy makers, practitioners, and others, understand, use, or do not use scientific findings when making decisions (Wyborn et al. 2017, Crawford et al. 2019). The conventional “knowledge deficit model” assumes that scientific knowledge is transferrable, and if made available to policy makers and practitioners will be used to inform evidence-based decisions (Cash et al. 2006). However, this transactional view does not sufficiently account for the dynamic knowledge development required to engage effectively with complex evolving global issues like disaster risk (Cash et al. 2003, 2006, Sinclair et al. 2012, Scheufele 2013, Wyborn et al. 2017, Fearnley and Beaven 2018, Sword-Daniels et al. 2018, Doyle et al. 2019). In these rapidly changing and often highly charged decision-making environments, interactions and processes connecting science, policy, and practice

have been found to be highly context-specific, complex, and dynamic (Wyborn et al. 2017). This recognition is driving more collaborative and iterative approaches to managing the science-policy-practice interface (Thompson et al. 2017, Wyborn et al. 2017, 2019). Science engagement of this kind includes what is known as “cocreation,” which has been defined as the process of jointly producing knowledge with one or more others (Mauser et al. 2013, Rock et al. 2018). There is growing evidence that involving researchers can enhance the scientific credibility of processes and knowledge, while consideration of appropriate values, interests, concerns, and circumstances from multiple perspectives contribute to the perception that processes and knowledge are also of practical use, and legitimate (Cash et al. 2002, 2003, Lacey et al. 2018). The use of formal structures that aim to balance the practical knowledge and professional experiences of practitioners and policy makers with the rigor and credibility provided by scientists can further enhance the legitimacy of disaster risk knowledge (Beaven et al. 2016, Wyborn et al. 2017, Fearnley and Beaven 2018, McLennan et al. 2020).

Growing demand for collaborative approaches is driving efforts to support large cross-sector and interdisciplinary initiatives in order to address complex, global issues such as DRR. We report on the use of a case study to investigate the development of a large New Zealand cross-sector, interdisciplinary, disaster risk management initiative, Project AF8. Although the use of a specific case means that findings cannot be used as the basis of generalized empirical knowledge, case studies can provide a more detailed understanding of a phenomenon of interest (Stake 1995). Focusing on a specific cocreation initiative has the potential to offer greater insights into the processes used to generate and exchange multidisciplinary disaster risk knowledge, and, by documenting challenges and successes, provide practical guidance for future efforts (Reed et al. 2014, Cvitanovic et al. 2018).

METHODS

Case study

Project AF8 (AF8) is a large, government-led, cross-jurisdictional initiative established to support planning and preparation for a major earthquake in the South Island of New Zealand, using a scientifically robust scenario of a magnitude 8.0 earthquake along the Alpine Fault (Orchiston et al. 2016). This tectonically active island nation in the Southern Pacific has a history of frequent seismic activity (MCDEM 2007). Earthquake hazard and risk has been long recognized, and has informed initiatives that aim to reduce disaster risk. These include disaster risk governance, including land use planning (IFRC 2014); strict enforcement of high seismic standards in building codes (New Zealand Legislation 2019a); a well-developed emergency management sector (MCDEM 2017a); relatively high public levels of disaster awareness (MCDEM 2016); very high levels of insurance uptake (ICNZ [date unknown]); and sustained investment in hazard and risk assessment (Cowan et al. 2008, EQC 2020).

The South Island has a population density of ~7.3 people per square kilometer (Statistics New Zealand 2019). Distributed across six regions, two unitary authorities, and 17 subregional districts (Terralink International 2010), this population includes many small rural communities that are highly dependent on distributed critical infrastructure systems (New Zealand Treasury

2015). Much of the nation’s economy is based on primary industries, and associated processing sector, accounting for 11% of gross domestic product in 2017, and 80% of national exports in 2019 (Statistics New Zealand 2017, MPI 2019). Because this production occurs predominantly in rural regions, the impacts of a large magnitude earthquake on rural communities can have national implications (Spector et al. 2019).

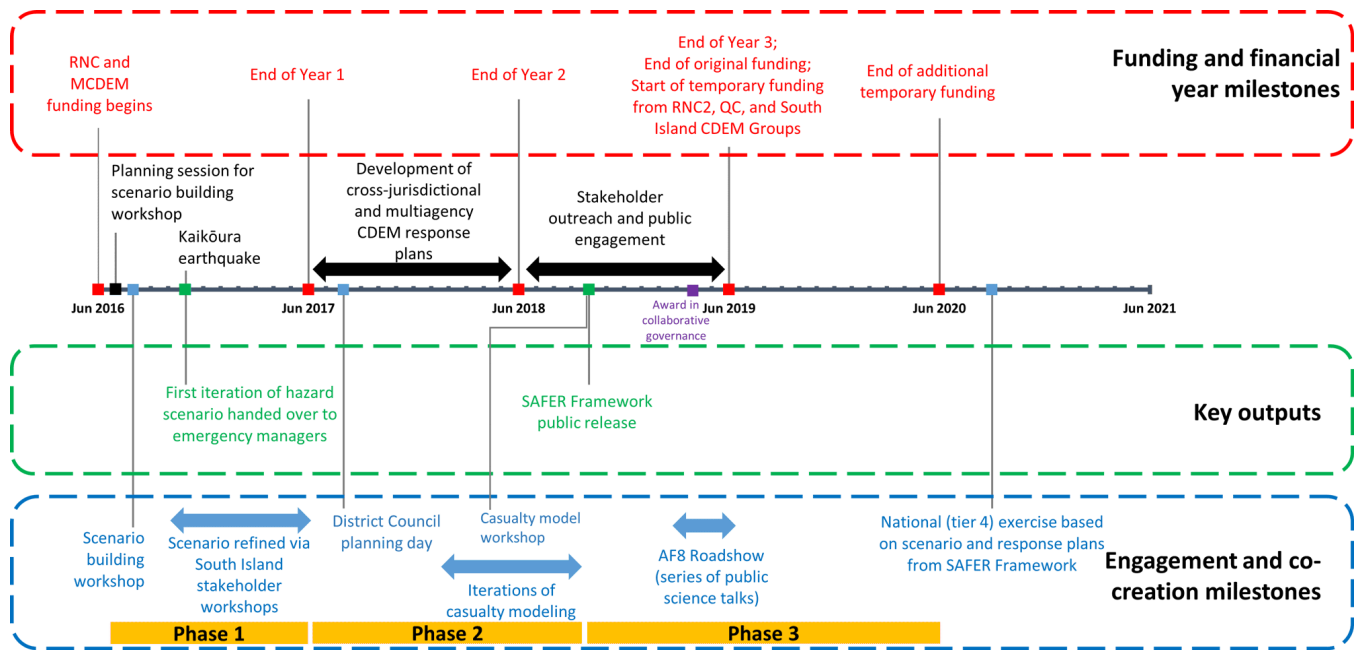
Over the last decade, two South Island earthquakes have resulted in 187 fatalities (185 due to the 2011 Christchurch earthquake and 2 caused by the 2016 Kaikōura earthquake) and thousands of injuries (Johnston et al. 2014, MCDEM 2017b, Horspool et al. 2019). Widespread damage to infrastructure contributed to local, regional, and national disruption, making these disasters socially disruptive (Potter et al. 2015, Stevenson et al. 2011, 2017) and costly in monetary terms (NZ\$25 billion/US\$16.8 billion in insured losses [ICNZ date unknown]). Both disasters also boosted funding for earthquake and disaster research, and the growth of collaborative networks linking scientists and response and recovery agencies (Beaven et al. 2017, Woods et al. 2017). The damage and disruption caused by the Kaikōura earthquake also provided useful insights for the AF8 initiative concerning the potential rural impacts of a major regional earthquake on national and local distributed infrastructure networks, rural and isolated communities, primary industries (pastoral farming, viticulture, and seafood sectors), and the tourism sector, which relies heavily on New Zealand’s natural environment.

Project AF8 is focused on the likely impacts of a future earthquake on the Alpine Fault (AF), a plate boundary fault that runs along the west coast of the South Island. Highly active, and 350 kilometers long, the risk it poses has made it the focus of sustained research (Cooper et al. 1987, Bull 1996, Norris and Cooper 2001, Berryman et al. 2012, Howarth et al. 2018), and of emergency management policy and practice (Ministry of Civil Defence 1990, Orchiston et al. 2016). Recent scientific studies have identified 27 seismic events over the last 8000 years on the southern segment of the AF alone (Cochran et al. 2017). This evidence provides a 29% conditional probability of that segment rupturing again within the next 50 years (Cochran et al. 2017). A full length rupture along the AF (moment magnitude 8.0) is expected to generate strong initial ground shaking, a long and potentially complex aftershock sequence, and coseismic hazards including landslides, landslide dams and subsequent outburst flooding, lake seiches, liquefaction, and large-scale sediment transport and aggradation in rivers; the impacts of these hazards are expected to have national implications (Robinson and Davies 2013, Bradley et al. 2017a, b, Orchiston et al. 2018).

Project AF8 was established to coordinate efforts to plan and prepare to coordinate response to a South Island earthquake disaster across local, regional, and national levels (Project AF8 2019). The project combines scientific modeling, emergency response planning, and community engagement to better understand the hazard consequences to the people, communities, industries, and infrastructure of the South Island (see Orchiston et al. 2018 for an account of the development of AF8 and its outcomes).

Under the Civil Defence and Emergency Management Act 2002, DRR at local and regional levels in New Zealand is coordinated by 16 regional Civil Defence and Emergency Management

Fig. 1. Detailed time line of major Project AF8 milestones, including key moments of the funding cycle, main generated outputs, and processes.



(CDEM) Groups, each a consortium of local and regional authorities, emergency services, lifeline utilities, and regional offices of government departments (NEMA 2013). Project AF8 is unusually cross-jurisdictional in that it is the first project to regularly bring representatives from a number of different CDEM Groups together. Initially funded by the National Emergency Management Agency (NEMA), formerly known as the Ministry of Civil Defence and Emergency management, AF8 has also benefitted from considerable aligned research funding from Resilience to Nature’s Challenge and QuakeCoRE programs (Fig. 1).

Hosted by Southland CDEM Group, AF8 is led by a dedicated project manager, and collaboratively governed by a formal steering group consisting of that manager, one lead scientist, and six senior emergency managers (one from each South Island CDEM Group). This structure informed a strong AF8 focus on the planning needs of professional emergency management, and on associated oversight of disaster response operations from across the South Island. The collaborative involvement of hazard and risk specialists from physical, engineering, and social science communities in ongoing scenario development, AF8-related research, and AF8 community outreach was formalized through the inclusion of the lead scientist in the steering group, who was tasked with liaising informally with that wider scientific community (Orchiston et al. 2018).

The project is organized around the three CDEM Group objectives relating to a large AF earthquake: to improve understanding of the consequences of a future event, to increase readiness and response capabilities across the South Island, and to engage and share learnings with the wider public (Project AF8 2019). Delivery of the first objective was supported through the

cocreation of a maximum credible event scenario, which used up-to-date scientific knowledge on seismic hazards and impact modeling to outline the likely impacts of a given magnitude 8.0 AF earthquake. In support of the second objective, AF8 used this scenario to map out a cross-jurisdictional and multiagency approach to a South Island disaster response, while the third objective continues to be supported through AF8 engagement with the public and interested organizations through a public education campaign.

The AF8 project built on decades of national disaster risk and emergency management policy iterations (e.g., the Civil Defence Emergency Management Act 2002) and earthquake research funding (e.g., through the Earthquake Commission). It also utilized findings from more recent government-funded research programs focused on disaster risk as an issue of national importance, including the Natural Hazards Research Platform 2009–2019 (<https://www.naturalhazards.org.nz/>; Beaven et al. 2016), Resilience to Nature’s Challenge 2015–2025 (<https://resiliencechallenge.nz/>; MBIE 2019), and QuakeCoRE 2015–2020 (<http://www.quakecore.nz/>). This national investment in mission-led research is consistent with international trends, e.g., the European Commission’s “Societal Challenges” (<https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges>).

Project AF8 is unusual, however, among comparable issue-based New Zealand initiatives, in that although operationalized with support from New Zealand science programs, project strategy is led and decided by a steering group consisting almost entirely of CDEM practitioners. By contrast, researchers lead both the Wellington-based “It’s our Fault” research program, and the “DEVORA” investigation of volcanic hazard in Auckland,

working closely with CDEM and other government decision makers (see also Table 1). The AF8 arrangement, in which researchers provide support for a government-led planning initiative, relied on (and resembles) the collaborative response and recovery relationships developed during and after the 2010–2011 Canterbury Earthquake Sequence (Beaven et al. 2016) and the 2016 Kaikōura Earthquake (Woods et al. 2017). These relationships also underpinned the immediate precursor for AF8, Exercise Te Ripapaha. Initiated by Canterbury CDEM Group, Te Ripapaha was conducted in mid-2013 to test inter- and intra-dependencies between the six South Island CDEM Groups and other major stakeholders in the event of a major natural disaster (Robinson et al. 2014). This one-off, 24 hour simulation exercise was based on a scientific AF earthquake scenario collaboratively developed by South Island AF hazard and risk specialists and the Canterbury CDEM Group (Robinson et al. 2014). A group of approximately five scientists (the core group) who led and coordinated AF8 scenario development included several scientists involved in the development of the Te Ripapaha AF scenario.

Data gathering

The objectives of the research reported in this article were to gain insight into the processes used to cocreate AF8 knowledge, into the value of the knowledge produced to those involved, and into perceived challenges and successes. To meet these objectives case study data was gathered through participant observation, through interviews with a range of practitioners and members from the core group of scientists, through a focus group with steering group members, and from desktop review of relevant peer-reviewed literature and grey literature (including AF8 reports, publications and press-releases, and other government documentation, legislation, and guidelines available in the public domain). Ethical review and approval was obtained from the University of Canterbury’s Human Ethics Committee (reference number: HEC 2017/34/LR-PS).

Participant observation data was drawn from the active involvement of several authors in the early development of the strawman scenario, the initial AF8 workshop, and subsequent scenario development in which the AF8 scenario and outputs were iteratively refined in collaboration with practitioners. Participant observation also involved attendance, observation, note taking, and active participation in a selection of AF8 meetings and outreach activities. Participant observation data was supplemented by data provided to the lead author during $n = 3$ one-on-one interviews with scientists (including the lead scientist) involved in coordinating the AF8 science collaboration and the iterative development of the scenario (Table 2).

An additional $n = 17$ semistructured interviews (bringing the total number of interviews to $n = 20$) were conducted by the lead author with a purposive sample of practitioner participants identified and recruited based on professional involvement in AF8 at local, regional, and / or national levels (Table 2). Open-ended questions were designed to gauge insights into cocreation processes, and perceptions of the value offered by the disaster risk knowledge cocreated through the AF8 initiative. Most interviews were conducted face-to-face, but some were conducted over the phone.

Table 2. Role and distribution of interview participants.

	Operate:		
	Locally	Regionally	Nationally
Practitioners	4	9	1
Policy makers	-	1	2
Scientists		3	

An AF8 Steering Group focus group ($n = 5$) facilitated by the lead author was conducted with the project manager, the lead scientist, and three of the six CDEM Group representatives. The discussion was guided by questions similar to those used in interviews. Data was collected between September 2017 and August 2018.

Practitioner interviews began with AF8 Steering Group members and were progressed through the use of the “snowballing” technique; they ended once the authors determined data saturation had occurred (Ritchie et al. 2003). Participation was voluntary and confidential. Interviews were digitally recorded and in most cases professionally transcribed. All transcripts were cross-checked by the lead author before being validated by the relevant participant. A confidential records management process was established, ensuring that data was stored on password protected files on confidential University of Canterbury servers.

Data analysis

Data analysis began in February 2018, continued through the data gathering phase, and was largely completed by January 2019. Transcribed data was manually coded by the lead author using a general inductive process (Ritchie et al. 2003, Thomas 2006). Text segments were extracted and entered into a spreadsheet, where they were assigned summary words or phrases, and grouped into themes and categories by the lead author (Boeije 2002). As themes began to emerge the lead author compared them with each other and with the raw data, in an iterative process that took several months. Data analysis was loosely guided by the following research questions:

1. What knowledge was cocreated through AF8, for what purposes, who was involved, and how valuable (or not) was the knowledge?
2. What cocreation processes were used, at what AF8 stage, and what made these more or less valuable to practitioners and scientists?
3. What cocreation challenges emerged as AF8 developed, and what factors enabled cocreation?

These questions were used to provide a broad frame of reference, rather than informing expectations concerning specific findings (Thomas 2006). Analyses of documents and transcripts were carried out separately, allowing analysis outcomes to be compared to each other, and to establish findings (Ritchie et al. 2003, Thomas 2006). Coding was then cross-checked by other authors, and discussed with practitioner stakeholders, as best practice when it comes to auditing the dependability of the findings (Thomas 2006).

RESULTS

Data analysis produced themes that related to each of the objectives, in a process that triangulated multiple perspectives to provide insights into the evolution of this cocreative initiative over time, the value of cocreated AF8 knowledge and cocreation processes, and factors that inhibited or enabled cocreation. We report these findings chronologically, according to identified phases within the AF8 initiative.

Chronological overview

The AF8 project began with a two-day scenario-building workshop in August 2016 (Fig. 1), attended by selected steering group emergency managers, the core group, and approximately 30 other AF scientists. Steering group practitioners provided advice concerning their requirements, and scientists workshopped three broad scenario elements: earthquake source (e.g., epicenter, ground motion), geomorphic consequences (e.g., landslides, surface deformation), and impacts on social and built environments. Workshop outcomes included the decision to use a maximum credible event AF8 scenario, and a short-term work plan to develop and deliver this scenario to the steering group.

The first version of the scenario was delivered to the steering group three months later (Orchiston et al. 2016; Fig. 1). Throughout 2017, the scenario was refined through subsequent workshops with the six South Island CDEM Groups, tailored for the relevant context with local and regional level impacts incorporated into the base hazard and impact scenario. Over the same period aligned research findings addressed priority topics requested by the steering group. Findings and workshop feedback were considered and incrementally incorporated into the base scenario by the core group of scientists.

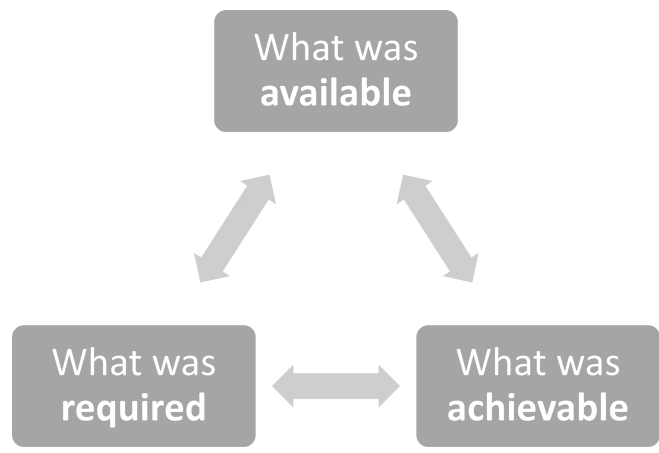
In the second year of the project, facilitated discussions between the six CDEM Groups were held to enhance multiagency AF response across jurisdictional boundaries. The resulting emergency response priorities were combined with the scenario that had been created through iterative cocreation between scientists and emergency manager stakeholders during the first year of the project, to form the South Island Alpine Fault Earthquake Response (SAFER) framework (Project AF8 2018). This document presented a timeline of estimated response challenges within the first seven days of an event, and mapped out a set of synergistic operational objectives for all six South Island CDEM Groups.

The AF8 focus in year three was outreach and communication. A series of public talks and secondary school presentations, the AF8 Roadshow, aimed to enhance public awareness of both the risk posed by an AF earthquake, and of options to participate in planning and preparation for such an event. This South Island-wide campaign stimulated and addressed the public demand for disaster risk knowledge manifested in rising numbers of requests for presentations to community groups, schools, and organizations. At the time of writing (late 2019), over 150 AF8 presentations have been given, reaching an audience of nearly 9000 people (Project AF8 2019). In April 2019, AF8 won the BERL Award for excellence in Collaborative Government Action from the New Zealand Society of Local Government Managers (SOLGM 2019). The perceived value of this collaboration, including the regular contact between South Island emergency managers, has led to exploration of transitioning this three-year project into an ongoing “Programme AF8.”

Evolving cocreation over time

From the outset, AF8 was required to engage head on with the fundamental problem it aimed to address, the complex and widespread confusion regarding the disaster risk knowledge that was (1) required of AF8 by stakeholders, (2) scientifically available, and (3) scientifically achievable (Fig. 2). This three-way confusion was informed by, and illustrates the effects of, the institutional misalignments that give rise to tensions around the science-policy-practice interface (Cash et al. 2003, Parker and Crona 2012, Sarkki et al. 2014, Wyborn et al. 2017). Reducing this confusion remained the central AF8 mission, because it required nothing less than collective knowledge of what practitioners needed from AF8, and of the limitations and potential of the available and achievable science used in this project to address that need. Although this collective knowledge grew over the course of the project, the cocreative processes through which this occurred were complex and far from linear. All those involved lacked knowledge of at least some aspects of what was needed, available, and possible at all AF8 stages.

Fig. 2. Conceptual diagram showing the tension seen during Project AF8 between required, available, and possible disaster risk knowledge.



Phase 1: early scenario development: June 2016–May 2017

As a CDEM-led project, AF8 sits largely in the government domain. This position underpins the formal AF8 governance structure, in which seven practitioners and one lead scientist make up the steering group responsible for AF8 strategy, and for interfacing with scientist and South Island practitioner communities. The resulting science-practice balance is consistent with recent New Zealand government practice, in which individual science advisers are co-opted from research organizations to provide “a trusted bridge” between science, society, and the relevant government agency (OPMCSA 2018, Jeffares et al. 2019). The use of a single “knowledge broker” to manage the science-policy-practice interface is an emerging international trend (Wyborn et al. 2017, Cvitanovic et al. 2018). In the AF8 Steering Group, this role constituted the primary interface between the steering group and the scientific communities.

The first objective for AF8 was to collate and build on current scientific knowledge to develop a scenario that could inform

emergency response planning (Orchiston et al. 2018). Tasked by the steering group with coordinating the creation of a “maximum credible” AF event scenario, the lead scientist convened a small (~5) core group of scientists to plan the first step, a two-day scenario-building workshop. Like most cocreation initiatives (Reed et al. 2014, Datta et al. 2018, Cvitanovic et al. 2018) the AF8 science collaboration developed out of existing relationships. The scientists planning this workshop had been centrally involved in the collaborative research response following the 2010–2011 Canterbury Earthquakes, the South Island wide 2013 Te Ripapaha scenario-based Alpine Fault response exercise, and the intensive round of broad informal collaborations in 2014 and 2015 required to bid for Resilience to Nature’s Challenge funding (MBIE 2013). This context informed the identification of three workshop aims: (a) identify the greatest sources of uncertainty (and gaps) in current disaster risk knowledge, including hazard, impact, and risk assessment science; (b) agree on a scenario development process that would include all available / willing AF scientists, at least in the initial stages; and (c) determine what disaster risk knowledge would be most valuable for emergency managers in order to decide scenario content (Orchiston et al. 2018). The approach to scientific collaboration at the time was particularly evident in the aim to include all available / willing AF scientists.

A lot of very gifted, very motivated scientists ... have worked on ... AF8, also on Alpine Fault stuff for a long time [so] as we developed that scenario it was very important that they were part of it and that they felt that their science was being used and utilized (scientist 2018).

In August 2016, the scenario building workshop began with a briefing from the AF8 Steering Group members to the ~35 attending AF scientists concerning the knowledge they hoped to gain from the AF rupture scenario. This brief was necessarily high level rather than detailed because the practitioners involved were not aware of the research capabilities of the scientific community. Scientific discussions began using talking points drawn from a “strawman” scenario, developed by the early scientist group, to provide preliminary guidance and direction.

Balancing the focus of workshop discussions proved challenging. Guidelines provided to workshop participants required the identification of the science and metrics, i.e., what to measure, available and required for three broad aspects of an AF scenario: earthquake source (e.g., epicenter, ground motion), geomorphic consequences (e.g., landslides, surface deformation), and impacts on social and built environments. More broadly, the workshop was designed to ensure that roughly equal focus was devoted to all three workshop objectives, which were to agree on the following: the available and required science; a scenario development process; and the type of scenario that would best suit the needs of stakeholders.

As the workshop unfolded, however, much of the intensive workshop discussion remained focused on the science and metrics available and required to ensure that the earthquake source material used in the scenario was robust. This focus was driven by the large number of well-intentioned and motivated physical-process and hazard scientists attending the workshop, who led intense debates about often highly technical aspects of a potential future AF earthquake. These discussions also gave rise to tensions

concerning which aspects of AF science should and would feature prominently in the scenario. For steering group members these discussions were enlightening.

I think there was actually a realization by all of them that they are all working in the same field, but [were] perhaps not joining a lot of what they are doing up (steering group practitioner 2018).

The lengthy debates focused on the physical science of an AF rupture were also perceived to have thrown the objectives of the workshop out of balance.

That’s one of the major findings we should report from this, is not to get too lost in the physical science [detail]. As long as everyone’s got an opportunity to make sure that they’re inputting, and that the best science is being used for what is needed, that’s good. But ... we should [have been] much more consequence focused. Sixty percent of effort [went] into something that [contributed] 5% or 10% of the credibility or importance of the scenario (scientist 2018).

The need to focus on hazard consequences from the outset was also emphasized by a national level practitioner involved in the inception of the AF8 program:

So the research into the hazard we understand is critical to get there, but for us the more useful part of it is the “so what,” the implications of the hazards and the risks (national level practitioner 2018)

At intervals scientists convened with practitioners to discuss issues and potential options before engaging in further scientific debate. On day two of the workshop scientists invited steering group practitioners to better constrain and clarify the knowledge they required from the scenario, and the ways in which they planned to use it. As the workshop drew to a close, it became clear there would not be sufficient time for deliberative discussion of the scenario development process, or the scientifically informed discussion required to identify a scenario format best suited to the needs expressed by practitioners. As the need to choose a scenario and preferred risk metrics became urgent, those involved made rapid decisions to settle on the specific values that would inform a single “maximum credible event” AF scenario before the workshop ended.

Because it determined the scenario content, this workshop laid the foundation of subsequent knowledge development, disaster response planning sessions, and public engagement events across all three phases of AF8. The core group of scientists that emerged from this initial workshop to lead and coordinate scenario development included hazard and risk specialists involved in the development of the Te Ripapaha AF scenario as well as engineers specializing in infrastructure and ground motion modeling. It is useful to think of the workshop focus, i.e., the AF rupture scenario, as a boundary object as defined by Star (2010). Shared by several different groups, e.g., scientists, emergency management practitioners, policy and decision makers, and, in Phase 3, community groups or other stakeholders, this scenario served to focus the discussions and exploration of options required to build the collective understanding of what knowledge was scientifically available, scientifically possible, and necessary for disaster risk planning purposes (Impedovo and Manuti 2016).

The first version of the scenario was provided to the AF8 lead scientist for delivery to the steering group in November 2016 (Fig. 1). In the same month the Kaikōura Earthquake catalyzed interest in AF8 across the South Island and at national level, and boosted disaster related science-policy-practice activity and funding. The increased focus on earthquake risk contributed to high levels of interest in Phase 1 AF8 workshops held with South Island CDEM Group stakeholders in the ensuing six months. Each workshop was led by the relevant CDEM Group, supported by the presence of two to three core group scientists, and involved representatives from local government, infrastructure providers, health and social services, the private sector, and iwi. Iwi are indigenous New Zealand tribal organizations with a suite of traditional rights and responsibilities arising from historical and contemporary interests in a particular rohe or area (Te Puni Kōkiri [date unknown]). In this officially bicultural nation, agencies govern in formal statutory partnerships with relevant iwi (Te Puni Kōkiri [date unknown]).

Other Phase 1 interactions between the steering group and the scientists developing the scenario continued to be largely mediated by the lead scientist, as per the steering group structure. This contributed to a challenge that emerged quickly in Phase 1, as steering group practitioners needed early work from the scientists developing and refining the scenario in a time frame that aligned with their professional timetables. It has been well established that practitioners typically require evidence in the short term, and that this requirement is fundamentally misaligned with the comparatively time-consuming processes required to develop scientifically credible knowledge (Cash et al. 2003, Parker and Crona 2012, Sarkki et al. 2014, Beaven et al. 2017). Scientists typically work largely autonomously (Bruneel et al. 2010, Sarkki et al. 2014), and increasingly within multiyear funding mechanisms that contribute a degree of freedom to prioritize topics as required, but add to overall workloads. Senior research scientists involved in the AF8 scenario development, for example, were managing multiple priorities because of academic demands and involvement in a number of parallel projects, which added to the time required for further scenario development.

Typical of science-practice-policy collaborations (Parker and Crona 2012, Sarkki et al. 2014), these mismatched time frames were compounded to some extent in Phase 1 by the steering group structure. Required to serve as the main conduit between the steering group and the scientific community, the role of lead scientist included relaying steering group requests to relevant scientists, collating responses and delivering them to the steering group. The steering group interface with practitioner communities occurred through the pre-existing formal CDEM Group structure, which was designed to interface with a broad range of stakeholders at regional level. Because there was no comparable formal structure to extend the scientific interface (either pre-existing, or established as part of AF8), interactions between the lead scientist and the scientist coordinating the development and refinement of the scenario necessarily occurred informally, using emails and meetings as and when required to convey steering group requests and collate scientist responses. In Phase 1, this reliance on a single individual to interface with the science community added administrative and time costs that contributed to the pressure on scientists and a degree of practitioner frustration. This structure was also perceived by some

to have hindered cocreation in the early stages because it did not provide the regular opportunities for practitioners and scientists to discuss requirements and possible options face-to-face required to reduce confusion around what practitioners required, what scientists were providing, and what they might be able to provide.

For the most part, participants recognized these early challenges as important steps in the process required to advance AF8. For practitioners, the intense debates of the initial workshop provided a valuable window into scientific processes and capacities, and underlined both the need and the value of face-to-face collaboration.

[W]e had, I don't know, 50 odd scientists around the country who were doing earthquake research. And just to sit there and watch all these different disciplines and all these different organizations ... I think for us to actually see what the capabilities of the science community are, and for them to actually see what our needs as practitioners are, has been a real win for the project (steering group practitioner 2018).

This first phase of scenario development and ongoing refinement was also of value in that it considerably reduced confusion about available and possible scientific knowledge concerning earthquake disaster risk.

There'd been some truly excellent hazards-based research done on the Alpine Fault ... so it was quite well understood that there was a big national risk. But no one had pushed into the consequences terribly hard ... being able to translate some of that hazard information into a realistic footprint with a spatiotemporal intensity was really, really fundamental. [Developing] this systematic and more robust scenario development process ... really exposed the lack of knowledge around vulnerability and how those consequences should be and could be calculated (scientist 2018).

Phase 2: scenario refinement and response planning: June 2017–October 2018

Phase 2 further refined the disaster risk content of the scenario on two fronts. The CDEM system was used to engage with wider emergency management practitioner, policy maker, and other stakeholder communities such as local government, critical infrastructure organizations, health and social services, and private sector organizations, responding to early demand for AF8 support. For example, in response to a district council request, AF8 material was used as the basis of an emergency management planning workshop in the Canterbury region on 31 August 2017 (see Fig. 1). In the morning AF8 scientists and local emergency managers presented the likely hazards, processes, and local consequences of an AF earthquake, and responded to intensive questions from the audience. In the afternoon, District Council staff used the morning session and AF8 material as the basis of a response planning exercise. Resources provided by AF8 deemed of particular value by the participants in this planning session included audio-visual presentations of scientific data (including animated modeling of the ground motion expected to be caused across the South Island by an Alpine Fault rupture), and hand-outs and posters such as maps indicating disaster risks and likely

impacts to communities and critical infrastructure over time. These resources fed directly into community response plans for parts of the district, as well as police and local government response plans for an AF event, demonstrating early practice and policy impacts of the disaster risk knowledge generated and shared through AF8.

This scenario refinement process continued to reveal gaps in the science, and the deployment of research funding to address them, from the Resilience to Nature's Challenges and QuakeCoRE programs in particular. This allowed AF8 researchers to recruit and resource doctoral students to investigate additional high-priority AF8-related topics requested by the steering group, as part of the wider aligned research effort contributing to modeling and outputs that were more useful for stakeholders.

For example, critical infrastructure providers required disaster risk knowledge generated by AF8 to inform their own modeling of loss-of-service interdependencies and network resiliency design. In response to a steering group request for subregional network analysis for critical infrastructure, doctoral research used sequenced participatory workshops with infrastructure providers and emergency managers (throughout October, November, and December 2017) to cocreate the service outage and interdependency knowledge required to refine the AF8 model (Davies 2019). Each workshop began with a brief AF8 presentation of likely hazards and impacts. This material informed a subsequent expert judgement exercise, in which participants discussed and agreed on estimates of likely service outages at different time points following the earthquake, marking them on impact maps generated using the AF8 scenario (Davies 2019). In the final workshop, representatives of all the infrastructure providers, emergency managers, and residents of a small, remote community situated directly over the Alpine Fault used the resulting maps to collaboratively identify the likely consequences of service outages over time on that community following an AF earthquake, and discuss mitigation and response options (Davies 2019). As the research progressed, and each workshop informed the maps that were provided for the next, the likely consequences of infrastructure interdependencies on different South Island communities at different points in response and recovery became clearer, generating a spatiotemporal intensity sequence of outage data that was fed into both AF8 and infrastructure provider modeling of infrastructure interdependencies and network resilience (Davies 2019).

In the first few months of Phase 2 the lead scientist continued to act as the conduit for interactions between the steering group and the scientists coordinating scenario-development. The growing complexity of the scenario and the associated science, together with the much wider range of stakeholders involved put pressure on this arrangement, giving rise to the need to scale up cocreation efforts.

The immediate trigger for this change of approach was the need for disaster casualty metrics. Both scientists and practitioners recognized that estimates of likely casualties and deaths could be highly uncertain, and politically charged.

[Y]ou plan for the worst and hope for the best so I think just a realistic stab at [likely] casualties would be helpful, but the trouble is when that gets out in the public arena it can be really unnerving (steering group practitioner 2018).

[A]s soon as you put deaths on a map and you put the number in front of people, that is all they think about. So, we have been really careful about not putting any of those numbers in front of the media because of the uncertainty of how accurate they are ... They don't give a damn about the range. But for me, it is really important that I understand the uncertainty around those numbers (steering group practitioner 2018).

Casualty modeling conducted in response to a steering group request was initially conducted for the AF8 scenario using an existing model, but was subsequently found to require large assumptions, scaling of international data and models to the New Zealand context, and lacked adequate input data. Because these limitations were inherent to the base model, the casualty estimates it produced had such a wide uncertainty range they were determined to not be fit for AF8 purposes. To address this problem, AF8 modeling scientists and the steering group convened in October 2017 to conduct an expert judgement exercise and develop an appropriate approach for assessing potential casualties for AF8 purposes (Fig. 1). Informed by expert practitioner and scientific judgement, the resulting methodology produced casualty estimates with an uncertainty range more aligned with practitioner need and AF8 modeling requirements.

In addition to producing an acceptable method for assessing casualties, the casualty modeling workshop also contributed to a new collective recognition of the value of using intensive face-to-face cocreation to reduce confusion around what was required, scientifically available, and scientifically possible.

[W]hen [named scientist] presented that [named model] data and he went through it step by step and said this is a caveat for these bits and these are the limitations, this is what this bit means and then I can look at what is presented and go right, I really like that bit, I am going to take that, and this bit I am going to take to that meeting (steering group practitioner 2018).

After this workshop the AF8 cocreation process became more adaptive, scaling up and adapting interactions to allow for periods of more time- and resource-intensive cocreation when required. Face-to-face interactions between modeling scientists and steering group practitioners were recognized as a necessary part of identifying aspects of confusion concerning what was needed, available, and possible, making the process of identification an ongoing dynamic, rather than a static exchange.

Previously we probably didn't know what format they [scientists] could do it in and I probably didn't know what our requirements were. And that is where Project AF8 really works: it's the ongoing conversation. Somebody like [named scientist] can say look, we can present it in this way or we can do it this way and then I just go, oh, I didn't know you could do that (steering group practitioner 2018).

As the casualty modeling workshop revealed, intensive interactions were particularly useful when agreeing on what constituted an acceptable level of uncertainty for particular metrics. The practitioners and policy makers who participated in this study were flexible when it came to coping with high uncertainty in disaster risk knowledge. Aware of how important it was to understand the level of uncertainty in any given metric,

and how it had been estimated, most practitioners expected to rely largely on their own expert judgment when using estimates to make decisions in any given context. Agreeing on acceptable levels of uncertainty for any given metric was necessary, however, to identify the point at which the knowledge produced by the AF8 scenario was good enough for practitioner planning and decision-making purposes.

The more adaptive approach to cocreation adopted in Phase 2 to allow the process to scale up interaction between scientific modelers and practitioners (with other perspectives feeding in where necessary) substantially enhanced the collective understanding of all involved concerning what was required to cocreate disaster risk knowledge that was scientifically adequate and fit for use in practice within the New Zealand context. This finding is consistent with other recent research finding that knowledge-sharing is substantially improved when scientists, stakeholders, and other end users regularly discuss disaster risk uncertainty face-to-face (Cvitanovic et al. 2015, Bradley et al. 2017c, Fearnley and Beaven 2018, Doyle et al. 2019).

Phase 3: public outreach: October 2018–June 2020

Phase 2 ended in October 2018 with the publication of the SAFER Framework, outlining operational roles and responsibilities for each CDEM Group within the first seven days of an AF8 earthquake (Project AF8 2018). In Phase 3, the focus shifted to outreach, using the knowledge developed through the scenario in Phases 1 and 2 in intensive public education campaigns (such as the AF8 Roadshow) and presentations to a wide range of stakeholders. These occurred at local, regional, and national levels, and were aimed at public, private, and government organizations. The outreach style of Phase 3 continued to be collaborative, since AF8 scientists and practitioners recognized that joint presentations increased public perceptions of the scientific credibility of the earthquake risk and likely consequences, and the value of the plans to mitigate them.

The best thing that the community can see, is a scientist standing beside a practitioner, saying “we believe that this is what’s going to happen from a science perspective,” and the practitioner saying, “and understanding that, this is how we intend to deal with it,” because that gives people confidence (steering group practitioner 2018).

Codelivered presentations provided credibility to practitioner messaging in the eyes of the audience.

It gives us a bit of robustness in our discussions with the wider stakeholders that it is not just scaremongering, there is actually some thought behind what we are talking about (steering group practitioner 2018).

Perhaps the greatest challenge in Phase 3 was to navigate the perceived tension of generating enough understanding of the risk posed by a large AF8 earthquake to stimulate awareness and mitigation activity, but not to overwhelm stakeholders to the point where they felt fatalistic. Practitioners and scientists agreed that while achieving this relied on striking an appropriate balance between presenting the extent of the natural earthquake processes and the range of likely consequent impacts, the real key was to present consequences that related directly to the stakeholders.

[F]or example, you show the likelihood that the event might occur, and particularly the [ground motion]

modeling, people are ... terrified ... then when we pull in the hazard and risk modeling and show here’s what we think the consequences would be, yeah it is bad, but they can benchmark it against something ... and they can say, oh well actually, most people are going to live through this, and okay so we actually need to do something, rather than, you know, the side of New Zealand’s going to fall off (scientist 2018).

[T]his is what shaking means but this is what the impact is going to be on you ... that is where people actually wake up and go, oh ... this is what is going to happen to me. And that is the only way they really relate to it (steering group practitioner 2018).

At the national level, a number of large government agencies have approached AF8 seeking cocreated outputs. A steering group practitioner reported, by way of example, an agency that experienced infrastructure disruption and associated logistical and security issues during the 2010–2011 Canterbury Earthquake Sequence. Data provided by the agency was incorporated into the AF8 scenario to create bespoke disaster risk knowledge that was then utilized by the agency’s in-house emergency planners.

Reflections

Because most of the interviews were conducted toward the end of the AF8 project, most participants took the opportunity to offer reflections on the wider project, cocreation knowledge gains and challenges, and future possibilities. The following discussion reports on themes that emerged from this data.

Disaster risk knowledge required by practitioners

Most interviewed practitioners emphasized the value of knowledge that directly addressed the first two AF8 themes: to improve understanding of the consequences of a future event, and to increase readiness and response capabilities across the South Island. This meant that they were most interested in potential disaster impacts to populations, i.e., individuals and communities.

Modeling the spatiotemporal intensity not only of unfolding hazards, but also of community impacts, loss of service, and the effects of response and recovery interventions was highly valued because understanding the way these might unfold over time increased practitioner capabilities when planning for medium- and long-term response and recovery. Disaster response often hinges on the access required to move people out of high hazard zones and to bring in vital goods and rescue specialists, so detailed knowledge of the way that critical infrastructure (such as road, power, and telecommunications networks) was likely to perform during and after a disaster was particularly useful.

What I want to know is what’s that going to look like on the ground? What am I going to be faced with? Are we still going to be able to drive through that area? ... What does that mean for that community? Are they trapped, are they out of power, are they out of water and all of those things? I can put plans in place to deal with that ... before it happens. There’s a lot of preplanning that we can do around that, and even if it’s loose numbers (steering group practitioner 2018).

As this would suggest, modeled disaster risk knowledge concerning likely impacts in the initial hours (to days) following

a disaster was particularly valuable for practitioners, because response coordination and operational decision making immediately after a major event is necessarily based on very limited knowledge of the unfolding situation.

[In the first 12 hours] you're spending time trying to find out what the impact is. ... If, in a perfect world, you had some modeling that could tell you, you might save a bit of time and be ready for it (steering group practitioner 2018).

Early AF8 modeling efforts provided broad indications of likely impacts to the built environment. Maps indicating expected loss-of-service to critical infrastructure (such as the coseismic hazard maps found in Robinson [2014]) were particularly well received. As the AF8 initiative progressed, and the scenario evolved, AF8 disaster impact modeling became more sensitive to spatiotemporal variations, and also more accessible, to better meet a wider range of practitioner and policy-maker needs.

[T]he value that I think this projects really got through to, it's created a scenario that everybody can understand. So, the hazard information that sets this up is compelling, but by being able to translate through into consequence information, that people can tangibly get their hands on, they can start seeing how their organization, or their household, or whatever, how that might be affected (scientist 2018)

The science-policy-practice interface

Two broad trends characterized the evolution of AF8 cocreation processes: the phased engagement informed by the AF8 plan, and the increase in intensive cocreation that was required as the project gathered pace. Project AF8 unfolded in a sequence that required each phase to provide the outcomes required by the next, and that continued to increase the number and range of stakeholders involved. In Phase 1 the steering group worked with scientists and South Island CDEM Groups to develop the AF8 scenario. Phase 2 scenario refinement and response planning used workshops and research that involved a much wider range of stakeholders, while Phase 3 involved broad public outreach (Fig. 3). As the project focused on the distinct goals and challenges of each phase, new disaster risk knowledge was generated, partly through changing perceptions and experiences of the collaboration process. This kind of phased approach is broadly consistent with best practice participatory approaches, which require that phased and sequenced participation is tailored to fit the relevant context (Ross et al. 2002, Hurlbert and Gupta 2015, Aoki 2018).

Overall, AF8 processes were both iterative and adaptive, sitting toward the cocreation end of the engagement spectrum (Ross et al. 2002, Hurlbert and Gupta 2015, Aoki 2018, Rock et al. 2018). It is also clear that AF8 became more adaptive and cocreative as it developed, in response to the increased complexity and demands of the Phase 2 collaboration, and as collective understanding of the knowledge required for the project developed. Phase 3, involving scientists and practitioners in AF8 copresentations to a range of stakeholder groups, was perceived to have enhanced both the legitimacy of the content and the value of public messaging (Fig. 4). Copresenting scientists were able to explain the underlying research and limitations of the AF8 modeling (i.e., enhancing credibility), laying the basis for practitioner presentations, who

Fig. 3. Nested phases of Project AF8 engagement process.

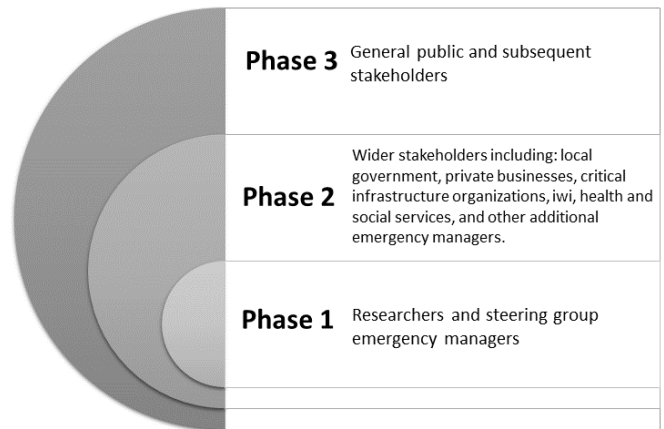
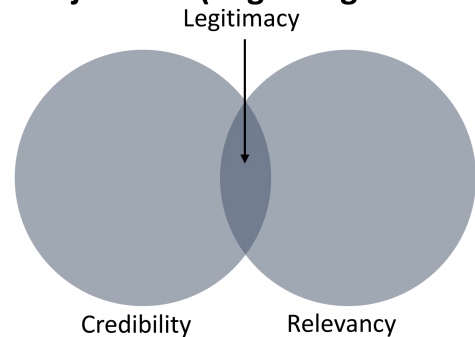
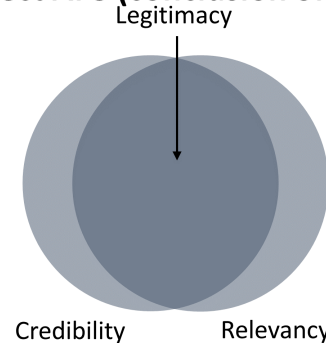


Fig. 4. Conceptual diagram of relative changes over time to the credibility, relevancy, and legitimacy of the Project AF8 knowledge and processes (adapted from Fearnley and Beaven 2018).

Start of Project AF8 (beginning of Phase 1)



End of Project AF8 (conclusion of Phase 3)



used that evidence-based research to support their messaging (i.e., enhancing relevance).

The journey from the collaborative style established in the initial workshop and informed by the steering group structure to the more adaptive and intensive cocreation that developed in Phases 2 and

3 (Fig. 4) was difficult and highly complex. With the benefit of hindsight, this journey might have been fast-tracked by the development of a more balanced cocreation structure from the outset, codesigned by practitioners and core group scientists to balance the ratio of practitioners to scientists on the steering group, provide for more intensive cocreation throughout, and clearly assign AF8-related roles and responsibilities. There is now considerable evidence that this kind of formal collaborative structure can reduce the disruptive effects of institutional misalignments at the science-practice-policy boundary in complex policy contexts, including disaster risk management (Beaven et al. 2017, Wyborn et al. 2017, 2019, Datta et al. 2018, Fearnley and Beaven 2018). This approach would have facilitated a broader interface between AF8 and with the wider scientific community, and reduced the widespread confusion concerning the knowledge required, available, and achievable that made the initial workshop particularly challenging. Focusing on the development of a formal structure to manage science-practice-policy cocreation from the start however would have required a substantial departure from the precedent set by the science-policy-practice collaborative style that had developed in the preceding five years, in which science support for government disaster risk management remained largely informal (Beaven et al. 2016, Woods et al. 2017). Even when initiated in the science domain, where the vast majority of documented cocreation initiatives begin, most cocreation emerges and develops organically out of existing informal collaborative relationships, rather than through scientifically informed collaborative design (Cvitanovic et al. 2018).

Participants were unanimously positive about the AF8 process, identifying the use of cocreation to generate and disseminate AF8 disaster risk knowledge as key to achieving collective recognition of the knowledge of most value to practitioners, collective understanding of the limitations and possibilities of scientific knowledge, and collective knowledge of disaster risk and resilience.

[T]he AF8 project has been a revelation I think for all six of us ... to be able to work hand in glove, and make really good sound decisions, based on the best science ... has been brilliant I mean it really is the way of the future as far as managing hazards go (steering group practitioner 2018).

[T]he ... [enhanced] level of disaster risk and resilience literacy that has transformed the entire group ... through this process has been really substantial, and the level of sophistication at which we can talk to each other now because of this process is immense (scientist 2018).

Future directions

Although in agreement concerning the importance of continuing the AF8 collaboration, participants were also highly aware that the three way tension between what is required, what is scientifically available, and what is scientifically achievable remained a highly dynamic process that was in a constant state of change. By greatly reducing confusion about fundamental scientific approaches and broad practitioner needs, the collective knowledge gained over the course of the project also raised collective awareness of the need to ensure that the scenario

remains current with respect to changing practitioner requirements and the rapid pace of scientific and technical developments.

Looking forward, scientists were interested in building from the knowledge gained through AF8 to develop more dynamic modeling that is better able to predict and anticipate future trends, and suggested that a move to more modular formats would make it easier to keep the scenario current, and to devolve presentation delivery and knowledge cocreation to the local level. Practitioners expressed similar concerns about the need to keep the scenario scientifically current and responsive to their changing requirements, and suggested that spatiotemporal modeling that included a range of hazard sources (floods, droughts, weather events, volcanic activity) and supported a greater focus on risk management over time would be particularly valuable.

CONCLUSION

The AF8 initiative is unusual in that it is a government-led planning project based on the collaborative development of a scientifically credible scenario, and tailored to the specific hazards and political, natural, and social environments in rural and urban South Island New Zealand settings. A degree of collaboration mandated by the CDEM Act 2002 (New Zealand Legislation 2019b) has contributed to a collaborative culture within the CDEM sector and critical infrastructure groups (MCDEM 2017a). Recent earthquake disasters have seen this collaboration informally extend to include members of the science community because of science collaboration with response agencies (Beaven et al. 2016, Woods et al. 2017). It is likely that this collaborative context drove high initial levels of commitment to AF8 that provided early gains in making the scenario and the disaster risk knowledge it provided relevant to practitioner needs. These gains led in turn to demand from other sectors, such as insurance, additional government agencies, schools, and community groups. The collaborative development of knowledge and outputs that incorporated the operational implications of future disasters made both highly applicable to pre-event planning.

Cocreation was required to build collective knowledge of the institutional constraints on both science and practice, and of the need for (and value of) intensive face-to-face interactions. Generated over time, this collective understanding facilitated cocreation of shared knowledge of what practitioners required from AF8, and of the scientific findings and techniques that could be used to meet those needs.

Cocreating the knowledge required of sensitive disaster impacts that are inherently uncertain, such as modeled casualty estimates, was particularly challenging. Identifying the acceptable level of uncertainty in this, and other instances, although not an explicit AF8 goal, was necessary to identify the point at which modeled disaster risk knowledge became “good enough” for practitioners. Project AF8 practitioners necessarily rely on qualitative judgment and their own disciplinary, organizational, and cultural expertise to determine this threshold, and understand it to be highly context-dependent. The cocreation environment made possible to identify this threshold on a case by case basis, as part of ongoing iterative interactions between scientists and stakeholders.

Like most documented cocreation initiatives, AF8 also found developing cocreative processes initially challenging. In hindsight, this development would probably have benefited from

the collaborative design of a transparent cocreation structure at the outset, which clearly identified agreed goals and assigned roles and responsibilities. Relying on informal collaborative relationships and the high pre-existing levels of trust and goodwill between members, AF8 evolved instead around the multihazard impact scenario, which served as a boundary object, holding diverse aspects of the cocreation process together. The focus on a scientifically robust disaster scenario helped this large, government-led disaster management planning project develop into a forum for sustained dialogue between scientists and practitioners, generating enduring collaborative relationships and mutual understanding of professional needs and limitations.

Ultimately the broad lessons from AF8 add weight to other findings concerning the coproduction of knowledge and decision making in the disaster risk and resilience context (see, for example, Oven et al. 2016, Datta et al. 2018, Robinson et al. 2018). The value of the AF8 initiative lies as much in the cocreation processes that evolved over time as it does on the knowledge that was created. Balancing the influence and needs of stakeholder and research communities served to enhance the legitimacy of both processes and outputs, particularly in the outreach phase, where knowledge sharing was enhanced when researchers and practitioners workshopped AF8 knowledge with communities. Raising disaster risk literacy among all involved, the AF8 cocreation process increased the sophistication of both disaster response planning and spatiotemporally intensive disaster impact modeling. These lessons are likely to be of particular value to those initiating other large interdisciplinary initiatives centered around the research-practice interface, particularly in disaster risk reduction and emergency management contexts.

Responses to this article can be read online at:
<http://www.ecologyandsociety.org/issues/responses.php/11928>

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Data Availability:

The data used in the manuscript is not publicly available because of ethical restrictions. The information contained within the recorded audio files and transcribed interviews could compromise the privacy of research participants.

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