Public health implications of multiple disaster exposures

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Disasters are an important public health issue; however, there is scarce evidence to date on what happens when communities and populations experience more than one disaster. This scoping review identifies literature on the effects of multiple disasters published until Aug 2, 2021, 1425 articles were identified, of which 150 articles were included. We analysed direct and indirect public health implications of multiple disasters. Our analysis suggests that exposure to multiple disasters can affect mental health, physical health, and wellbeing, with some evidence that the potential risks of multiple disaster exposure exceed those of single disaster exposure. We also identified indirect public health implications of multiple disaster exposure, related to changes in health-care facilities, changes in public risk perception, and governmental responses to multiple disasters. We present findings on community recovery and methodological challenges to the study of multiple disasters, and directions for future research.

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Introduction

Disasters can lead to short-term and long-term effects on physical and mental health, and can indirectly affect health and wellbeing as a result of evacuation, social disruption, financial loss, lifestyle change, damage to health-care facilities, and changes to the wider political and socioeconomic context.[1,2] Historically, disasters have been considered as rare, singular, discrete events. However, in the past 10 years, there has been increasing recognition of the ways in which disasters can overlap.[3,4] In March, 2011, the northeast region of Japan experienced the Great East Japan Earthquake, which led to a tsunami and subsequently to a nuclear disaster—an event that is often referred to as the 3.11 triple disaster.[3] In 2017, Hurricane Harvey resulted in a chemical plant explosion in Texas, USA, in addition to flooding and fires.[5] There are many examples of multiple disaster events occurring together, and the past year highlights overlaps between the COVID-19 pandemic and other types of disaster globally.[4,6] In the context of projected increases in disasters as a result of climate change,[7–9] and already high frequencies of exposure to overlapping disasters, there is a need to understand the ways in which multiple disasters can affect population health, wellbeing, and recovery processes, and the extent to which these effects might differ from those of single disasters.

In the past 5 years there has been a growing body of theoretical and conceptual work to understand so-called cascading disasters (disasters generating secondary disasters), compound disasters (combinations of simultaneous or successive extreme hazard events), and recurrent disasters (in which the same hazard repeats; table).[10–16] However, unclear and inconsistent terminology is often used to describe multidisaster scenarios,[5,14–16] and wider understanding of the public health effects of these events is poor. The literature on cascading or compound disasters is often primarily focused on modelling risks and hazards and on the role of critical infrastructure,[5] whereas empirical research, especially on community-level or population-level effects and on long-term recovery processes, has been scarce. The extent of the literature on the public health implications of multiple disasters has been unclear.

In this scoping review we aim to identify empirical research on the public health effects of the exposure of individuals or communities to multiple disasters, and recovery from these events. We draw on the definition from the United Nations Office for Disaster Risk Reduction of a disaster as a "serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts."[17] When examining the public health implications of multiple disasters, we take an inclusive view as to what qualifies as a disaster. We build from work in disaster studies identifying the importance of accounting for not only the commonly recognised 'natural' and technological disasters, but also slow-onset disasters such as drought,[18] chronic disasters,[19] and neglected disasters that have received less attention because they are misunderstood or they do not fit into the clear categories of 'natural' or technological.[20] We approach this Review with recognition that all these disasters have the potential to co-occur, occur sequentially, or repeat, and we seek to identify existing literature on cases in which people or communities have experienced more than one disaster. The focus of this Review is on public health effects and the recovery process from past events, while recognising that exposure to multiple disasters can involve overlapping periods of preparedness, response, and recovery.

Methods

Through this scoping review we examined the extent, range, and nature of research activity[21] on multiple disasters, public health, and recovery. We sought to include any empirical public health literature on previous cases of cascading, compound, or recurring disasters; however, considering the inconsistencies in terminology noted in previous papers, we also left scope to include multiple disaster scenarios that have been researched but not labelled in these ways. Our research questions, therefore, focus on multiple disasters rather than specifying disasters as cascading, compound, consecutive, or recurring. With a focus on identifying and

	Definition	Example
Consecutive disasters	"Two or more disasters that occur in succession, and whose direct impacts overlap spatially before recovery from a previous event is considered to be completed."[10] This definition includes successive compound disasters and cascading disasters.[10]	In 2008, Haiti was hit by multiple hurricanes. While still in the process of recovering from the hurricanes, Haiti then experienced a magnitude 7 earthquake in 2010 and a subsequent outbreak of cholera. These disasters have been labelled as consecutive disasters.[10]
Compound disasters	A term to describe natural hazards and the combination of two or more extreme events, which occur simultaneously or successively and have substantial effects.[11,15]	In 2012, Hurricane Sandy hit the New York metropolitan area. The unusual path of Hurricane Sandy was affected by multiple weather systems over the North American continent and the north Atlantic. This combination of multiple climate hazards, culminating in an unusual hurricane path and subsequent intense effects (widespread flooding), is referred to as a compound event.[15]
Cascading disasters	"Extreme events, in which cascading effects increase in progression over time and generate unexpected secondary events of strong impact. These tend to be at least as serious as the original event, and to contribute substantially to the overall duration of the disaster's effects."[13] A key element to cascading disasters is that they have a point of escalation, a crucial junction in a chain of reactions that leads to greater effects than the initial disaster would have done.[12] Cascading hazards, risks, and disasters have gained increasing attention since 2010.[3,12,15]	The 3.11 triple disaster in Japan in 2011 (earthquake that led to tsunami, which then led to nuclear disaster) is often described as a cascading disaster.[3]
Recurring or recurrent disasters	"The recurrence of a single natural hazard in the same geographic region over a one-year period."[16]	There was severe flooding in Pakistan in 2010, 2011, and 2012. Haiti experienced four hurricanes in 2008. These are two examples of recurring disasters.[16]

Table: **Terminology to describe multiple disasters**

collating learnings from past events, we constrained the focus of this Review to empirical studies from contexts in which people or communities had been previously exposed to more than one disaster. Specific inclusion terms are presented below. We followed the scoping review methodology outlined by Arksey and O'Malley,[21] and the principles for reporting in the PRISMA Extension for Scoping Reviews (appendix p 29).[22]

See Online for appendix

The following research questions were developed through preliminary literature searches and discussions with colleagues: what research has been done to examine the complexities of the public health effects of multiple disasters, and what research has been done to examine experiences of recovery from multiple disasters?

Data abstraction and content analysis

We abstracted data on publication information, study sites, multiple disaster constellation covered, methods, key findings, and any recommendations made in articles. We also noted if and how recovery was discussed, and detailed methodology information for studies on quantitative health outcomes.

We inductively created categories based on primary areas of focus (ie, mental health, physical health, etc). We then analytically grouped articles on the basis of their key themes into whether they covered direct or indirect implications for public health, informed by the framework outlined by Shoaf and Rottman.[1] Deaths, illnesses, and physical and psychological effects of multiple disasters were classified as direct implications, and any wider factors that could influence population health in multiple disasters were classified as indirect implications for public health.

Reflecting on the literature on methodological challenges to the study of (singular) disasters,[23] we also assessed articles for any methodological or conceptual challenges that were explicitly noted or implicitly apparent in relation to the study of multiple disasters.

Results

The 150 included articles (figure 1) were published between 1994 and 2021. Most of these articles (111; 74%) were published in or after 2014, highlighting that the public health implications of multiple disaster exposures is an emerging area of research. The articles covered a range of hazard constellations, and the lengths of time between each disaster ranged from minutes to years; the longest specified time between disasters was 25 years between the Good Friday earthquake and tsunami and the Exxon Valdez oil spill in southcentral Alaska, USA.[24] Some disasters were studied more frequently than others. One of the largest groups of articles focused on combinations of hurricanes—including some or all of Katrina in 2005, Rita in 2005, Gustav in 2008, Ike in 2008, and Isaac in 2012—and the Deepwater Horizon oil spill (2010) in the Gulf Coast of the USA (19 articles).[25–43] A further ten articles focused on some or all of these hurricanes but not on the oil spill.[44–53] Of all included articles, 71 (47%) covered cases of recurring disasters.[30,31,34,37,38,43–51,54–84] The full list of disaster cases covered in the included articles can be viewed in the appendix (p 1).

Most of the 150 included articles had a quantitative research design (98; 65%), with fewer qualitative (42; 28%) or mixed methods (10; 7%) studies. We present a detailed assessment of 67 quantitative health outcome studies in

the appendix (p 18); the majority (53; 79%) were cross-sectional studies with no comparison groups and sample sizes ranging from 100 to 5000. There were ten major population studies with more than 10 000 participants and ten studies that included comparison groups, whereas five studies had fewer than 100 participants.

We categorised articles on the basis of their primary topic of focus by frequency (figure 2). The following sections outline the identified direct and indirect implications for public health and the recovery process, and methodological challenges.

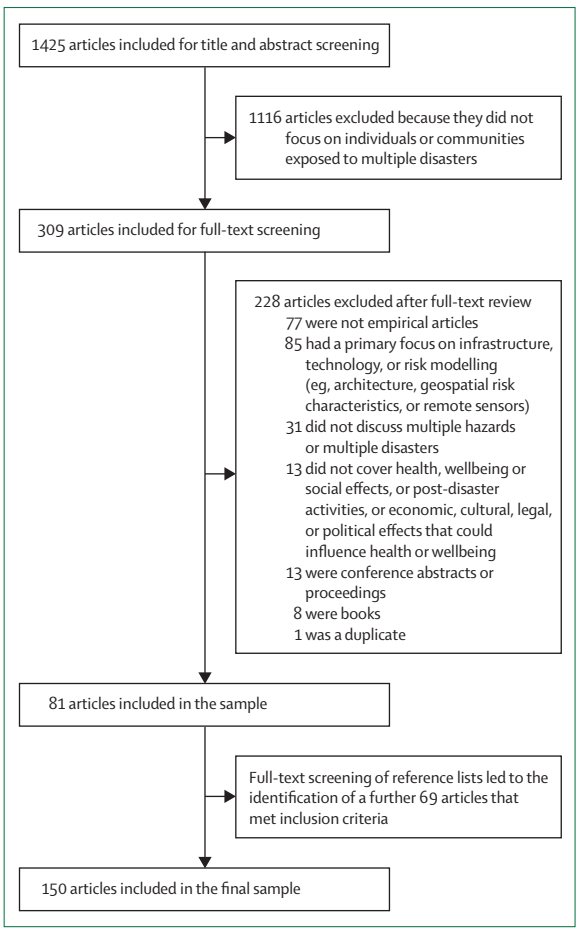

Figure 1: **Flow chart of included studies**

Direct implications for public health

Mental health

More than a third of included articles (53; 35%) focused on mental health in the aftermath of multiple disasters,[25–30,32,35–37,41,46,48,51,54,56–58,63,64,71,72,84–114] representing the largest theme identified. Numerous articles observed high rates of psychological distress, acute stress disorder, post-traumatic stress disorder, depression, panic disorder, or risk of suicide attempts in populations that had experienced multiple disasters.[36,54,56,64,84,90,93,97,98,110,112,114]

There were different approaches to study multiple disasters and mental health. Some studies compared the mental health risks from multiple (more than one) disaster exposures with the risks from a single disaster exposure, and found that multiple exposures were associated with increased risks to mental health (a cumulative effect).[37,41,46,71,85,97,98,109] For example, in a nationally representative survey of Australians, those exposed to multiple disasters across their lifetime were at significantly greater risk of suicide attempts than were those exposed to a single disaster.[98] Although some researchers have questioned whether exposure to one disaster could have a positive effect of preparing people mentally for future disasters, we identified evidence against this notion.[37,46,98] For example, Harville and colleagues[46] found that exposure to both Hurricane Katrina and Hurricane Gustav was associated with poor mental health, and that even when individuals perceived benefit after the first disaster, this benefit was not protective against the mental health effects of experiencing both disasters. Conversely, one study after the 9/11 terrorism attack (2001) and Hurricane Sandy (2012) found that previous high exposure to the 9/11 terrorism attack was associated with a weaker effect of Hurricane Sandy on post-traumatic stress disorder for older adults, but the opposite result was found for younger adults.[89] These findings represent an area in need of further study; however, from the articles identified in this Review, there were no consistent findings to suggest that experiencing one disaster could be protective against the effects of the next.

A group of studies found that mental health outcomes differed according to the severity of multiple disaster exposures (defined by one or more of degree of losses, damage, difficulties in accessing resources, perceived danger, or injuries experienced; appendix p 18).[46,64,100,105,106] Another subset of articles focused on the mental health of children who had experienced multiple disasters,[28,32,87,107,113] and found both cumulative effects and differences according to the severity of exposures. Another group of studies found that post-traumatic stress disorder from previous disasters can be exacerbated or reactivated after experiencing the next disaster, even if it is a different type of disaster. This occurrence was highlighted by studies that looked at populations exposed to both the 9/11 terrorism attacks and Hurricane Sandy in New York.[89,92,94,100,102,106]

Other articles on mental health included a group of studies that focused on the identification of socio-demographic characteristics associated with increased risk of adverse mental health outcomes following multiple disasters (eg, by age,[48,51] gender, educational attainment, financial hardship,[35,57] and temporary housing experiences[111]), with mixed results. Another group of articles focused on mental health risks faced by disaster responders[86,103,104] and public health workers[62,64] in the face of multiple disasters. There was also a group of studies that described alcohol-related and tobacco-related

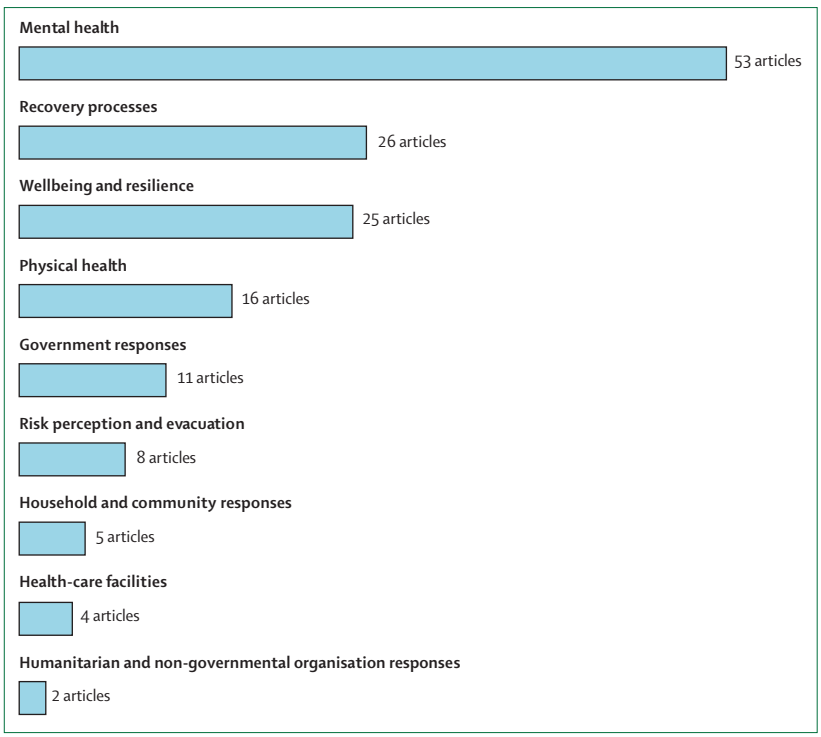

Figure 2: **Included articles by primary topic of focus (n=150)**

health behaviours and mental health in the aftermath of multiple disasters.[64,95,96,99,101]

Wellbeing and resilience

25 studies focused on factors influencing wellbeing and resilience in settings of multiple disasters,[31,33,34,38–40,42,44,45,47,49,50,55,62,68,77,82,83,115–121] including religiosity and the role of religion on coping,[38,40,45,47,49] social support,[45] the will to live,[116] gender,[45] perceived collective efficacy,[115,120] and perceived communal coping,[119] with mixed findings across different disaster contexts. One subset of articles focused on identifying patterns in positive emotions and post-traumatic growth following multiple disasters,[33,42,50,55,83,117,120] with some studies highlighting that hope and optimism[33] or psychological resilience[42] can be protective factors for mental health after multiple disasters or can facilitate coping and resilience after multiple disasters.[50] More widely, wellbeing and resilience have generally been insufficiently studied following multiple disasters. One systematic review that focused on the 3.11 triple disaster in Japan found numerous studies documenting mental health effects, although little research on the resilience of this population or on possible interventions to support wellbeing.[110]

Turning to barriers to wellbeing or resilience in settings of multiple disasters, one study found profound difficulties in balancing home and work responsibilities among workers in the Florida Department of Health who had to respond to four hurricanes in 2004, and who were, in many cases, affected by the hurricanes personally as well as professionally.[62] Cherry and colleagues[31] documented threats to cultural heritage, financial challenges, and lingering health concerns as major challenges faced by fishing communities in the Gulf Coast of the USA who were affected by Hurricane Katrina and the Deepwater Horizon oil spill. Two studies after the 2010 and 2011 Christchurch earthquakes in New Zealand found inequalities in trajectories of wellbeing and quality of life in the years following the earthquakes by income, ethnicity, and disability and physical health status.[118,121] Conceptualisations of resilience in multiple disaster contexts were also critiqued, with one study finding that people in poor neighbourhoods of Rio de Janeiro, Brazil, faced constantly recurring disasters and used resilience strategies as a necessity.[82]

Physical health

16 articles focused on physical health after multiple disasters.[75,76,79,80,122–133] One study, which looked at 500 communities across the USA, found that those who had experienced recurring disasters had increased incidences of asthma, high blood pressure, and self-reported poor mental health and poor physical health. Moreover, the incidence of all such outcomes increased with each additional year in which a community experienced a disaster.[128] After Hurricane Katrina and the Deepwater Horizon oil spill in the Gulf Coast of the USA, one study (focused primarily on mental health) found that people exposed to both of these disasters had more physical health symptoms than did populations exposed to only one of the disasters,[41] suggesting a cumulative effect. These studies highlight that exposure to multiple disasters can be associated with poorer self-rated health or increased physical health symptoms than exposure to one disaster.

Conversely, not all studies suggested a cumulative effect of multiple disaster exposures on physical health. One article on maternal and child health found that exposure to Hurricane Charley (2004) during pregnancy or shortly before conception was associated with increased risk of extremely preterm delivery; however, exposure to additional hurricanes did not seem to increase this risk further.[80]

There were also indications of a connection between mental health and physical health outcomes in settings affected by multiple disasters. One study in the Gulf Coast of the USA suggested that losses as a result of Hurricane Katrina were associated with subsequent distress related to the Deepwater Horizon oil spill, which in turn was associated with physical health symptoms—suggesting that mental health effects from disasters can be one pathway to physical health effects.[29] Hayashi and colleagues[127] similarly found that post-traumatic stress disorder and insomnia after the 3.11 triple disaster in Japan was associated with increased fracture risk among older adults. Several studies in this same context also found a substantial increase in diabetes,[129] bodyweight,

body-mass index, waist circumference,[131–133] and polycythemia[130] among populations exposed to the 3.11 disasters, with studies finding that those forced to evacuate were at greater risk of these outcomes than were non-evacuees.[129–131]

Other studies found an effect of emotional repression on immune parameters in populations affected by multiple disasters,[122] potential effects of multiple disaster exposures on child growth,[126] and patterns of waterborne and foodborne diseases after meteorological disasters.[79] Four articles focused on mortality after multiple disasters, including issues with death recording,[76,125] and physical and social determinants of mortality.[75,124]

Indirect implications for public health

Effects on health-care facilities

Four articles focused on health-care facilities in settings of multiple disasters.[134–137] Three studies found staff shortages in the aftermath of the 3.11 triple disaster in Japan,[135] which persisted for up to 18 months after the disaster and affected local health-care facilities.[136,137] One study looked at Hurricane Stan (2005) and a subsequent landslide in Guatemala and documented the immediate effects on one hospital, finding major structural damage but also a rapid recovery driven by a common vision shared by workers.[134] Across all identified cases, the affected hospitals continued functioning despite major logistical difficulties. Further research on indirect effects on patient care or on the health and wellbeing of hospital staff in multidisaster settings is warranted.

Risk perception and evacuation

Eight studies focused on public perceptions of risk and related behaviours in settings of recurring disasters, with mixed findings.[43,52,59,60,65,78,138,139] Smith and McCarty[60] found that, during the four hurricanes in Florida, USA in 2004, hurricane strength was the primary predictor of evacuation behaviours during each hurricane; however, increases in the numbers of hurricanes experienced had no effect on the likelihood of evacuating. Similarly, one study of 19 large earthquakes in Sichuan province (China) found that the severity of past disaster experiences was strongly correlated with perceptions of disaster risk, but the number of past disaster experiences was not.[138] Wang and colleagues[59] looked at public complacency (defined as the public believing that the threat would not happen and ignoring it, or not preparing for it, even if the threat appeared imminent) during the 2004 hurricanes in Florida, and found that public complacency peaked after three hurricanes. Other studies across different settings have similarly suggested a need for further work to improve communication and knowledge exchange between residents and government actors in settings affected by recurring disasters,[139] with one study underscoring that multiple disasters could provide a window of opportunity for agencies to engage citizens in preparedness.[65] Other studies have identified additional factors that might influence risk perception, evacuation decisions, or both in settings of recurring disasters, including gender,[43] the extent of losses in previous disasters,[78] and persuasion by family and friends.[52]

There is a need for further research on how experiencing multiple disasters can influence risk perception and public responses to risk, and the indirect implications there might be for public health as a result (ie, from non-evacuation or delayed evacuation).

Household and community responses

Five articles focused on strategies for coping with multiple disasters at the household and community level.[81,140–143] Bacon and colleagues[140] reviewed cumulative disasters in Nicaragua (coffee leaf rust from 2011 to present, drought in 2009, and Hurricane Mitch in 1998) and found a correlation between the coping responses that households used in past events and their continued use in subsequent disasters. Conversely, one study in Nebraska, USA documented various coping mechanisms for handling recurring severe drought in 2002–04 and 2012–14, and found that previous experience with the earlier drought resulted in different actions, including new water-conservation and land-use practices, in the later drought, with support from the government.[141]

Two studies examined the role of traditional knowledge systems of recurring disasters. Ngwese and colleagues[81] studied communities affected by recurrent flooding and droughts in Ghana, and found that communities used traditional knowledge systems to prepare for disasters, while often viewing these practices as having low efficacy. In a study of climate-related hazards in Cambodia, Pauli and colleagues[142] found that combining traditional knowledge and biophysical data could lead to a better understanding of so-called pressure points, at which the effects of recurring flooding become most severe, and the authors advocate for the co-production of knowledge between scientists and local communities.

Government responses

11 articles focused on government responses, including tensions in balancing national disaster management and local governance in multiple disaster settings,[144,145] disruptions in communications to citizens caused by additional disasters occurring,[146] and organisational learning in government responses to multiple disasters.[61,67,73,74,144–150] Kapucu and colleagues[61] found no evidence for improvement in emergency management responses to each of the four hurricanes that hit Florida in 2004. Similarly, one study reviewed government responses to disasters that occurred over the course of two decades in the USA,[147] and another reviewed disasters that occurred between 1996 and 2005 in the Netherlands;[148] both studies found that the same problems were often

repeated in government responses to multiple disasters without improvement. Nohrstedt and colleagues[149] found that the frequency and severity of disasters experienced in 85 countries were not associated with improved disaster risk reduction policies in those countries, even after controlling for income levels, types of disaster and starting policies.

There is some evidence of government learning in different contexts. For example, Brody and colleagues[74] looked at floods in Florida from 1999 to 2005 and found evidence for policy learning over time in local government. One study of emergency response in China found that government-organised response and rescue operations improved after the Wenchuan earthquake of 2008 and were more efficient and effective during the Lushan earthquake of 2013.[150] In another study, Corbacioglu and Kapucu[73] found evidence for organisational learning, but only after multiple disasters that culminated in one of devastating scale. Little organisational learning was seen in Turkish disaster management after the Erzincan, Dinar, and Ceyhan earthquakes between 1992 and 1998; however, the devastating earthquake in Marmara in 1999 led to changes in disaster management in Turkey.

There is a need for further research on the public health implications of government responses and governmental learning versus non-learning in multiple disaster settings (and related policy changes or non-changes), as an upstream structural determinant of health.

Humanitarian and non-governmental organisation responses

One study assessed the occurrence and effects of disasters in the southern Africa region between 2000 and 2012, with a focus on humanitarian responses, and found that smaller, subnational disasters were reoccurring and compounding large-scale disaster events.[151] However, this study found that large datasets often mask the effects of local and small-scale disasters, leading to bias in humanitarian disaster-relief responses, which focus on larger events. On a more local level, one study after the Nepal earthquakes in 2015 found that the operational reliance of non-governmental organisations on social capital to distribute support after a disaster contributed to inequities in access to resources.[152]

Recovery processes

26 articles focused on elements of recovery from multiple disasters, including economic recovery,[153,154] government and political factors in the recovery stage,[53,66,155–160] community capitals,[24] schools as central hubs for recovery,[161] disaster recovery committees,[162] inequalities in recovery,[163–167] and reconstruction experiences.[150,168–170] This group also included articles on programmes undertaken in a recovery setting in low-income and middle-income countries, including a food security and relief programme,[171] a microcredit programme,[172] a recovery aid programme,[69] and a global water, sanitation, and hygiene (WASH) programme.[70]

Some studies looked at individual or household recovery experiences (eg, of reconstructing housing, or settling insurance claims);[158,160,166,167,169,173] however, most focused on recovery at the community level[24,69,70,154,172] or the country level.[153,171] This focus was in contrast to some of the included mental health studies, which conceptualised individual-level recovery as the absence of mental health conditions or return to pre-disaster psychosocial or cognitive functioning.[28,48,83]

Few of the 26 articles identified provided a definition of recovery, and those that did gave different definitions.[160,163,166,167,169] The majority (23; 88%) of articles discussed recovery as a generalised concept, rather than recovery from multiple disasters. We identified only three articles that directly focused on the complexities of recovery from multiple disasters. Sargeant and colleagues[169] looked at the aftermaths of Typhoon Haiyan (2013) and Typhoon Haima (2016) in the Philippines and the Nepal earthquakes (April and May, 2015), and found that individual recovery was constrained by the continued need to respond to new cases of flooding, landslides, and monsoons. Ray-Bennett[172] suggested that multiple disasters can produce complex crises that make recovery tenuous, and Himes-Cornell and colleagues[24] emphasised the need for further research into what happens to communities that experience a disaster while they are still recovering from a previous one.

Challenges to researching multiple disasters

Conceptual and methodological challenges were identified in the study of multiple disasters. Many studies noted issues in defining and measuring multiple exposures.[28,41,85] Among quantitative studies on health outcomes (appendix p 18), there was a wide range of ways in which disaster exposure was defined and measured, and in some cases exposure was not measured directly. There was also a wide range of time periods covered between different disasters. For example, there were only 30 min between the 2010 Biobío earthquake and tsunami in Chile,[87,88] but 11 years between the 9/11 terrorist attacks and Hurricane Sandy in New York City.[106] However, we could not identify any clear evidence for differences in the effects of multiple disasters depending on the timescale between exposures or on hazard type (ie, differences in multiple exposures to the same hazard type versus different hazard types), representing a need for further research. Some studies noted that they were affected by methodological constraints that are common across disaster research, including the limitations of naturalistic study designs and the inability to draw causal conclusions,[26,28,29,32,55] absence of control groups,[110] and difficulties in tracking and including disaster-affected individuals who relocated out of study areas.[56,84]

Panel: **Recommendations for supporting public health in multiple disaster settings**

Mental health

- Provision of mental health support services to populations affected by cumulative trauma such as multiple disasters.[25,31,35,84,90,96,112,127]
- In mental health support interventions, screen for previous disaster exposures and other past traumas to identify populations at risk.[37,41,87,98,102,106]
- In counselling protocols, account for history of post-traumatic stress disorder symptoms from past disasters.[94]
- Whereas post-traumatic stress disorder and depression are commonly considered in public health screenings after a disaster, alcohol misuse, panic disorder, obsessive compulsive disorder and suicide risk are also relevant to screen for.[97,98]
- Mental health services should be widely offered in communities affected by multiple disasters, rather than waiting for people to seek out support.[35]
- Explore support options for children, young people, and families.[28,87,113]

Wellbeing and resilience

- Psychosocial support programmes after multiple disasters.[40,45,63,83,105,115]

Physical health

- Clinicians should be aware that experiencing traumatic events during multiple disasters can affect physical health,[25,123,129-131,133] and should screen for exposure to past disasters.[89]

Government responses

- Identify ways to improve links between governments and affected communities to enable more effective communication.[59,67,68]
- Improve opportunities for local government officials to connect with decision makers in central government,[157] and strengthen subnational governance and integration of non-governmental organisations to improve responses to consecutive disasters.[144]
- Develop new public policy strategies to support families affected by multiple disasters.[126]

Risk perception and evacuation

- Strengthen community groups and support community leaders to increase localised communication about risks of multiple disasters.[138]
- Create spaces in which local residents of disaster-affected places and governments can exchange information and experiences.[139]

Recovery

- Consider the historical nature of trauma in an area and recollections of past disasters when examining effects of present disasters and working on recovery.[92]
- Develop inclusive recovery frameworks, committees, and support programmes that recognise the needs of diverse communities.[118,162,165,166,169]
- Develop policy and interventions to support people in preventing, preparing for, and recovering from ongoing or recurring disasters.[164] Ensure that any recovery interventions do not overlook crucial social, cultural, political, and environmental factors that can influence the recovery process.[159,163,167]

It was notable that some articles (16; 11%) focused on a single disaster within a multi-disaster setting.[31,32,36,86,90,112,113,116,117,124,135,137,154–157] There were also numerous quantitative studies in which the entire study population was affected by multiple disasters, without comparison to populations affected by no disasters or only one disaster (appendix p 18). We identified only one article that engaged with theoretical literature on compound or cascading disasters.[151]

Discussion

Our Review suggests that multiple disasters can have direct and indirect effects on physical health, mental health, and wellbeing, with evidence of cumulative effects. Moreover, multiple disasters can affect health-care facilities, population risk perception and evacuation decisions, household and community responses, government responses, humanitarian and non-governmental organisation responses, and recovery processes, in ways that go beyond what is seen from single disasters.

We could not identify consistent individual-level risk factors for adverse outcomes following multiple disasters, with mixed results by age and gender. However, we found an emerging body of literature on the inequitable effects of multiple disaster exposures on physical health, mental health, and recovery processes at the community level. Hahn and colleagues[128] found that communities in the USA that had medium or high ratings on the Centers for Disease Control and Prevention Social Vulnerability Index (built from data on poverty levels, employment, educational attainment, and more) had the highest incidences of self-reported poor mental health, poor physical health, asthma, and high blood pressure after exposure to multiple disasters. Morgan and colleagues[121] found uneven trajectories of wellbeing and quality-of-life scores in the aftermath of the 2010 and 2011 Christchurch earthquakes in New Zealand. Those who had low income, were Māori, or who lived with a physical health condition or disability were more likely to experience lower quality of life and wellbeing in the long term. A group of studies following the 2015 Nepal earthquakes emphasised inequalities in long-term recovery trajectories,[163,166,167] finding that marginalised groups were more likely to face long-term displacement[164] and to be excluded from

Search strategy and selection criteria

The search strategy was informed by preliminary searches, and aims to account for different terms that are used to discuss multiple disaster scenarios. We searched Scopus, Web of Science, and PubMed from database inception to August 2, 2021, using the following terms: "cascading disaster*" OR "overlapping disaster*" OR "multi* disaster*" OR "compound* disaster*" OR "intersect* disaster*" OR "cumulative disaster*" OR "simultaneous disaster*" OR "concurrent disaster*" OR "consecutive disaster*" OR "repeat* disaster*" OR "recur* disaster*" OR "reoccur* disaster*" OR (multi* hazard*) AND (disaster* OR crisis OR crises OR emergenc*) AND recovery. This search resulted in 529 hits from Scopus, 931 from Web of Science, and 332 from PubMed. After 367 duplicates were removed, 1425 articles were screened.

We included peer-reviewed empirical academic articles published in English. Inclusion criteria were that articles focus on individuals or communities exposed to multiple disasters, and include discussion of the health, wellbeing, or social effects of these disasters; post-disaster activities; or economic, cultural, legal, or political effects that could influence health or wellbeing. To identify exposure to multiple disasters, we screened articles and included them for full-text screening if they either named more than one disaster (eg, the Great East Japan Earthquake and Fukushima Daiichi nuclear power plant disaster) or described scenarios in which more than one disaster occurs (eg, reference to recurring disasters), and indicated a defined population or place that experienced these disasters. Because of our focus on peer-reviewed empirical evidence, we excluded conference abstracts, theses, books, and theoretical or conceptual or commentary papers. We also excluded papers with a primary focus on infrastructure, technology, or risk modelling (ie, architecture, geospatial risk characteristics, or remote sensors).

Of the 1425 articles, 1116 were excluded during initial title and abstract screening because they did not describe a case of multiple disasters, leaving 309 articles for full-text screening. After this screening, 228 articles were excluded (figure 1) and 81 were included. The reference lists of all 81 included articles (apart from that of one systematic review) were then examined, and a further 69 articles that met the inclusion criteria were identified after full-text screening. With these, we included a total of 150 articles in the Review.

community-led reconstruction initiatives.[165] Still further research, policy, and recovery services will need to address inequities when advancing efforts to prevent, prepare for, respond to, and recover from multiple disasters.

Given the gaps we have identified, several recommendations can be made for further research. There is a need for further studies to examine differences between the effects of recurring disasters (of the same hazard type), and cascading disasters and consecutive disasters with different hazard types. Equally, there is a need for further research to investigate whether effects might differ depending on the timing between disaster exposures. There is also a further need for research on the psychological effects of repeat disaster exposure,[57,101] how previous disaster exposure affects the experience of any subsequent disasters,[25] the effect of multiple disasters on preparedness and recovery,[43] and the physical health effects of multiple disasters.[41] There is also a clear need to better understand the long-term effects of multiple disaster exposures.[33] In addition, although this Review has looked back at previous cases of multiple disaster exposures in individuals and communities, there is also a future-facing body of work on risk assessments (eg, in urban planning) and the all-hazards approach to disaster preparedness that will be relevant for reducing the public health risks of multiple disaster exposures.[174] Linking studies on the documented effects of past disasters with future-facing studies on modelling and reducing multi-disaster risks will be important in future work.

Recommendations for practice

In addition to the research recommendations that we have discussed, there are also several recommendations for practice that can be taken from this Review. There is scarce evidence to date on how to best support the health and wellbeing of people and communities after multiple disaster exposures. There is a pressing need for work on intervention programmes that are tailored to multi-disaster scenarios, given the ways in which the effects of these scenarios might differ from those of single disasters and the potential need for overlapping preparedness, response, and recovery activities in relation to different hazards. The panel summarises a range of recommendations for practice made in the identified articles, covering mental health, wellbeing and resilience, physical health, government responses, and recovery, and we suggest a need for integrated action across these categories. Many of these recommendations were similar to those made in the context of single disasters, for example providing widespread mental health support services. However, some recommendations were specific to multiple disasters, such as screening for past disaster exposure in interventions responding to new disasters.

Limitations

First, a general limitation of scoping reviews is that they do not systematically appraise the quality of evidence.[21] This approach is suitable for the current topic, given the emerging nature of knowledge on multiple disaster exposures, and the fact that public health implications have been studied by diverse disciplines and methods. The current findings could inform a further systematic review or meta-analysis (eg, focused on quantitative studies of mental health outcomes). Second, only English-language articles were included. Third, we categorised articles on the basis of the primary focus we identified

within them; however, there were cases in which the boundaries between categories (eg, between mental health and wellbeing) overlap. Fourth, because we were unable to include all potential combinations of hazard types in the search terms, this Review identified only cases that were described as multiple disasters; however, there are likely to be more cases than those actively described as such. For example, since completion of this Review, we have identified a relevant article on multiple disaster exposures that refers to people with multiple disaster exposures as exposure outliers.[175] Fifth, we recognise that the definition of where disasters begin and end can be unclear. There is increasing emphasis from some researchers that disasters should be thought of as processes, rather than events;[176] however, this framing was not present in most articles that we reviewed. Sixth, this Review focused on direct and indirect public health implications and the recovery stage of the disaster cycle, and did not include specified search terms on preparedness or resilience. Finally, we did not include grey literature in this review; however, the existence of increasing amounts of grey literature on multiple disasters should be noted.

This scoping review outlined existing research on the public health effects of multiple disasters and recovery from these disasters. We underscore the relevance of public health implications of multiple disaster exposures. Given the projected increases in extreme weather events owing to climate change, there is a pressing need to become better equipped to address public health in settings of multiple disasters.

Contributors

CL and LG conceived and designed the study. CL acquired and analysed the data. CL, LG, KB, LR, and PQ contributed to the interpretation of data. CL drafted the manuscript, and all authors revised it critically for important intellectual content. All authors give final approval to the version to be published, and agree to be accountable for all aspects of the work.

Declaration of interests

We declare no competing interests.

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References

1 Shoaf KI, Rottman SJ. Public health impact of disasters. *Aust J Emerg Manag* 2000; **15:** 58–63.

2 Nomura S, Parsons AJQ, Hirabayashi M, Kinoshita R, Liao Y, Hodgson S. Social determinants of mid- to long-term disaster impacts on health: a systematic review. *Int J Disaster Risk Reduct* 2016; **16:** 53–67.

3 Pescaroli G, Alexander D. Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Nat Hazards* 2016; **82:** 175–92.

4 Phillips CA, Caldas A, Cleetus R, et al. Compound climate risks in the COVID-19 pandemic. *Nat Clim Chang* 2020; **10:** 586–88.

5 Cutter SL. Compound, cascading, or complex disasters: what's in a name? *Environment* 2018; **60:** 16–25.

6 Usher K, Ranmuthugala G, Maple M, et al. The 2019–2020 bushfires and COVID-19: the ongoing impact on the mental health of people living in rural and farming communities. *Int J Ment Health Nurs* 2021; **30:** 3–5.

7 Intergovernmental Panel on Climate Change. Summary for policymakers. In: Masson-Delmotte V, Zhai P, Pirani A, et al, eds. Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2021: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf (accessed Sept 3, 2021).

8 van Aalst MK. The impacts of climate change on the risk of natural disasters. *Disasters* 2006; **30:** 5–18.

9 Sauerborn R, Ebi K. Climate change and natural disasters: integrating science and practice to protect health. *Glob Health Action* 2012; **5:** 1–7.

10 de Ruiter MC, Couasnon A, van den Homberg MJC, Daniell JE, Gill JC, Ward PJ. Why we can no longer ignore consecutive disasters. *Earths Future* 2020; **8:** 1–19.

11 Zscheischler J, Westra S, Van Den Hurk BJJM, et al. Future climate risk from compound events. *Nat Clim Chang* 2018; **8:** 469–77.

12 Alexander D. A magnitude scale for cascading disasters. *Int J Disaster Risk Reduct* 2018; **30:** 180–85.

13 Pescaroli G, Alexander DE. A definition of cascading disasters and cascading effects: going beyond the "toppling dominos" metaphor. Global Forum Davos. *Planet@Risk* 2015; **3:** 58–67.

14 Kappes MS, Keiler M, von Elverfeldt K, Glade T. Challenges of analyzing multi-hazard risk: a review. *Nat Hazards* 2012; **64:** 1925–58.

15 Pescaroli G, Alexander D. Understanding compound, interconnected, interacting, and cascading risks: a holistic framework. *Risk Anal* 2018; **38:** 2245–57.

16 Ferris E, Petz D, Stark C. The year of recurring disasters: a review of natural disasters in 2012. The Brookings Institution—London School of Economics Project on Internal Displacement. March, 2013. https://www.brookings.edu/wp-content/uploads/2016/06/Brookings_Review_Natural_Disasters_2012.pdf (accessed Sept 4, 2021).

17 United Nations Office for Disaster Risk Reduction. Disaster. https://www.undrr.org/terminology/disaster (accessed April 7, 2021).

18 Staupe-Delgado R. Progress, traditions and future directions in research on disasters involving slow-onset hazards. *Disaster Prev Manag* 2019; **28:** 623–35.

19 Rajan SR. Bhopal: vulnerability, routinization, and the chronic disaster. In: Oliver-Smith A, Hoffman SM, eds. The angry Earth: disaster in anthropological perspective, 1st edn. London: Routledge, 1999: 257–277.

20 Gaillard JC, Wisner B. An introduction to neglected disasters. *Jamba* 2009; **2:** 151–58.

21 Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol* 2005; **8:** 19–32.

22 PRISMA. PRISMA extension for scoping reviews. 2018. http://prisma-statement.org/Extensions/ScopingReviews (accessed April 26, 2021).

23 Stallings RA. Methodological issues. In: Rodrigues H, Quarantelli E, Dynes R, eds. Handbook of Disaster Research. New York, NY: Springer, 2007: 55–82.

24 Himes-Cornell A, Ormond C, Hoelting K, et al. Factors affecting disaster preparedness, response, and recovery using the community capitals framework. *Coast Manag* 2018; **46:** 335–58.

25 Osofsky HJ, Osofsky JD, Hansel TC. Deepwater Horizon oil spill: mental health effects on residents in heavily affected areas. *Disaster Med Public Health Prep* 2011; **5:** 280–86.

26 Walters AB, Drescher CF, Baczwaski BJ, et al. Getting active in the Gulf: environmental attitudes and action following two Mississippi coastal disasters. *Soc Indic Res* 2014; **118:** 919–36.

27 Shultz JM, Walsh L, Garfin DR, Wilson FE, Neria Y. The 2010 Deepwater Horizon oil spill: the trauma signature of an ecological disaster. *J Behav Health Serv Res* 2015; **42:** 58–76.

28 King LS, Osofsky JD, Osofsky HJ, Weems CF, Hansel TC, Fassnacht GM. Perceptions of trauma and loss among children and adolescents exposed to disasters a mixed-methods study. *Curr Psychol* 2015; **34:** 524–36.

29 Osofsky HJ, Hansel TC, Osofsky JD, Speier A. Factors contributing to mental and physical health care in a disaster-prone environment. *Behav Med* 2015; **41:** 131–37.

30 Cherry KE, Sampson L, Nezat PF, Cacamo A, Marks LD, Galea S. Long-term psychological outcomes in older adults after disaster: relationships to religiosity and social support. *Aging Ment Health* 2015; **19:** 430–43.

31 Cherry KE, Lyon BA, Marks LD, et al. After the BP Deepwater Horizon oil spill: financial and health concerns among coastal residents and commercial fishers. *Curr Psychol* 2015; **34:** 576–86.

32 Osofsky JD, Osofsky HJ, Weems CF, Hansel TC, King LS. Effects of stress related to the Gulf oil spill on child and adolescent mental health. *J Pediatr Psychol* 2016; **41:** 65–72.

33 Cherry KE, Sampson L, Galea S, et al. Optimism and hope after multiple disasters: relationships to health-related quality of life. *J Loss Trauma* 2017; **22:** 61–76.

34 Cherry KE, Sampson L, Galea S, et al. Health-related quality of life in older coastal residents after multiple disasters. *Disaster Med Public Health Prep* 2017; **11:** 90–96.

35 Blackmon BJ, Lee J, Cochran DM Jr, Kar B, Rehner TA, Baker AM Jr. Adapting to life after Hurricane Katrina and the Deepwater Horizon oil spill: an examination of psychological resilience and depression on the Mississippi Gulf Coast. *Soc Work Public Health* 2017; **32:** 65–76.

36 Cherry KE, Lyon BA, Sampson L, Galea S, Nezat PF, Marks LD. Prior hurricane and other lifetime trauma predict coping style in older commercial fishers after the BP Deepwater Horizon oil spill: prior trauma and coping. *J Appl Biobehav Res* 2017; **22:** e12058.

37 Harville EW, Shankar A, Dunkel Schetter C, Lichtveld M. Cumulative effects of the Gulf oil spill and other disasters on mental health among reproductive-aged women: the Gulf Resilience on Women's Health study. *Psychol Trauma* 2018; **10:** 533–41.

38 Stanko KE, Cherry KE, Marks LD, et al. When reliance on religion falters: religious coping and post-traumatic stress symptoms in older adults after multiple disasters. *J Relig Spirit Aging* 2018; **30:** 292–313.

39 Lee J, Blackmon BJ, Cochran DM Jr, Kar B, Rehner TA, Gunnell MS. Community resilience, psychological resilience, and depressive symptoms: an examination of the Mississippi Gulf Coast 10 years after Hurricane Katrina and 5 years after the Deepwater Horizon oil spill. *Disaster Med Public Health Prep* 2018; **12:** 241–48.

40 Cherry KE, Sampson L, Galea S, et al. Spirituality, humor, and resilience after natural and technological disasters. *J Nurs Scholarsh* 2018; **50:** 492–501.

41 Lowe SR, McGrath JA, Young MN, et al. Cumulative disaster exposure and mental and physical health symptoms among a large sample of Gulf Coast residents. *J Trauma Stress* 2019; **32:** 196–205.

42 Lee J, Blackmon BJ, Lee JY, Cochran DM Jr, Rehner TA. An exploration of posttraumatic growth, loneliness, depression, resilience, and social capital among survivors of Hurricane Katrina and the Deepwater Horizon oil spill. *J Community Psychol* 2019; **47:** 356–70.

43 Liddell JL, Saltzman LY, Ferreira RJ, Lesen AE. Cumulative disaster exposure, gender and the protective action decision model. *Prog Disaster Sci* 2020; **5:** 100042.

44 Broussard L, Myers R. School nurse resilience: experiences after multiple natural disasters. *J Sch Nurs* 2010; **26:** 203–11.

45 Brown JS, Cherry KE, Marks LD, et al. After Hurricanes Katrina and Rita: gender differences in health and religiosity in middle-aged and older adults. *Health Care Women Int* 2010; **31:** 997–1012.

46 Harville EW, Xiong X, Smith BW, Pridjian G, Elkind-Hirsch K, Buekens P. Combined effects of Hurricane Katrina and Hurricane Gustav on the mental health of mothers of small children. *J Psychiatr Ment Health Nurs* 2011; **18:** 288–96.

47 Tausch C, Marks LD, Brown JS, et al. Religion and coping with trauma: qualitative examples from Hurricanes Katrina and Rita. *J Relig Spirit Aging* 2011; **23:** 236–53.

48 Cherry KE, Brown JS, Marks LD, et al. Longitudinal assessment of cognitive and psychosocial functioning after Hurricanes Katrina and Rita: exploring disaster impact on middle-aged, older, and oldest-old adults. *J Appl Biobehav Res* 2011; **16:** 187–211.

49 Ai AL, Richardson R, Plummer C, et al. Character strengths and deep connections following Hurricanes Katrina and Rita: spiritual and secular pathways to resistance among volunteers. *J Sci Study Relig* 2013; **52:** 537–56.

50 Stanko KE, Cherry KE, Ryker KS, et al. Looking for the silver lining: benefit finding after Hurricanes Katrina and Rita in middle-aged, older, and oldest-old adults. *Curr Psychol* 2015; **34:** 564–75.

51 Jacobs MB, Harville EW. Long-term mental health among low-income, minority women following exposure to multiple natural disasters in early and late adolescence compared to adulthood. *Child Youth Care Forum* 2015; **44:** 511–25.

52 Adeola FO. Katrina cataclysm: does duration of residency and prior experience affect impacts, evacuation, and adaptation behavior among survivors? *Environ Behav* 2009; **41:** 459–89.

53 Darr JP, Cate SD, Moak DS. Who'll stop the rain? Repeated disasters and attitudes toward Government. *Soc Sci Q* 2019; **100:** 2581–93.

54 Grieger TA, Fullerton CS, Ursano RJ, Reeves JJ. Acute stress disorder, alcohol use, and perception of safety among hospital staff after the sniper attacks. *Psychiatr Serv* 2003; **54:** 1383–87.

55 Vázquez C, Cervellón P, Pérez-Sales P, Vidales D, Gaborit M. Positive emotions in earthquake survivors in El Salvador (2001). *J Anxiety Disord* 2005; **19:** 313–28.

56 Kiliç C, Aydin I, Taşkintuna N, et al. Predictors of psychological distress in survivors of the 1999 earthquakes in Turkey: effects of relocation after the disaster. *Acta Psychiatr Scand* 2006; **114:** 194–202.

57 Sattler DN, de Alvarado AMG, de Castro NB, Male RV, Zetino AM, Vega R. El Salvador earthquakes: relationships among acute stress disorder symptoms, depression, traumatic event exposure, and resource loss. *J Trauma Stress* 2006; **19:** 879–93.

58 Acierno R, Ruggiero KJ, Galea S, et al. Psychological sequelae resulting from the 2004 Florida hurricanes: implications for postdisaster intervention. *Am J Public Health* 2007; **97** (suppl 1): S103–08.

59 Wang XH, Kapucu N. Public complacency under repeated emergency threats: some empirical evidence. *J Public Adm Res Theory* 2008; **18:** 57–78.

60 Smith SK, McCarty C. Fleeing the storm(s): an examination of evacuation behavior during Florida's 2004 hurricane season. *Demography* 2009; **46:** 127–45.

61 Kapucu N, Bryer T, Garayev V, Arslan T. Interorganizational network coordination under stress caused by repeated threats of disasters. *J Homel Secur Emerg Manag* 2010; **7**: https://doi.org/10.2202/1547-7355.1629.

62 Herberman Mash HB, Fullerton CS, Kowalski-Trakofler K, et al. Florida Department of Health workers' response to 2004 hurricanes: a qualitative analysis. *Disaster Med Public Health Prep* 2013; **7:** 153–59.

63 Fullerton CS, Ursano RJ, Liu X, McKibben JBA, Wang L, Reissman DB. Depressive symptom severity and community collective efficacy following the 2004 Florida hurricanes. *PLoS One* 2015; **10:** e0130863.

64 Fullerton CS, McKibben JBA, Reissman DB, et al. Posttraumatic stress disorder, depression, and alcohol and tobacco use in public health workers after the 2004 Florida hurricanes. *Disaster Med Public Health Prep* 2013; **7:** 89–95.

65 McClure J, Henrich L, Johnston D, Doyle EEH. Are two earthquakes better than one? How earthquakes in two different regions affect risk judgments and preparation in three locations. *Int J Disaster Risk Reduct* 2016; **16:** 192–99.

66 Bakema MM, Parra C, McCann P, Dalziel P, Saunders C. Governance in shaky societies: experiences and lessons from Christchurch after the earthquakes. *Environ Policy Gov* 2017; **27:** 365–77.

67 Bakema MM, Parra C, McCann P. Learning from the rubble: the case of Christchurch, New Zealand, after the 2010 and 2011 earthquakes. *Disasters* 2019; **43:** 431–55.

68 Islam MR, Ingham V, Hicks J, Manock I. The changing role of women in resilience, recovery and economic development at the intersection of recurrent disaster: a case study from Sirajgang, Bangladesh. *J Asian Afr Stud* 2017; **52:** 50–67.

69 Muir JA, Cope MR, Angeningsih LR, Jackson JE. To move home or move on? Investigating the impact of recovery aid on migration status as a potential tool for disaster risk reduction in the aftermath of volcanic eruptions in Merapi, Indonesia. *Int J Disaster Risk Reduct* 2020; **46:** 101478.

70 Krishnan S. Humanitarian WASH (water, sanitation and hygiene) technologies: exploring recovery after recurring disasters in Assam, India. *Disaster Prev Manag* 2020; **29:** 629–42.

71 Bland SH, O'Leary ES, Farinaro E, Jossa F, Trevisan M. Long-term psychological effects of natural disasters. *Psychosom Med* 1996; **58:** 18–24.

72 Bland SH, Valoroso L, Stranges S, Strazzullo P, Farinaro E, Trevisan M. Long-term follow-up of psychological distress following earthquake experiences among working Italian males: a cross-sectional analysis. *J Nerv Ment Dis* 2005; **193:** 420–23.

73 Corbacioglu S, Kapucu N. Organisational learning and self-adaptation in dynamic disaster environments. *Disasters* 2006; **30:** 212–33.

74 Brody SD, Zahran S, Highfield WE, Bernhardt SP, Vedlitz A. Policy learning for flood mitigation: a longitudinal assessment of the community rating system in Florida. *Risk Anal* 2009; **29:** 912–29.

75 Ray-Bennett NS. The influence of caste, class and gender in surviving multiple disasters: a case study from Orissa, India. *Environ Hazards* 2009; **8:** 5–22.

76 Ray-Bennett NS. Disasters, deaths, and the Sendai Goal One: lessons from Odisha, India. *World Dev* 2018; **103:** 27–39.

77 Manock I, Islam R, Hicks J, Sappey RB, Ingham V. Perceptions of institutional and social response to frequent flooding in an Australian rural town. *Aust J Emerg Manag* 2013; **28:** 42–48.

78 Witvorapong N, Muttarak R, Pothisiri W. Social participation and disaster risk reduction behaviors in tsunami prone areas. *PLoS One* 2015; **10:** e0130862.

79 Na W, Lee KE, Myung HN, Jo SN, Jang JY. Incidences of waterborne and foodborne diseases after meteorologic disasters in South Korea. *Ann Glob Health* 2016; **82:** 848–57.

80 Grabich SC, Robinson WR, Engel SM, Konrad CE, Richardson DB, Horney JA. Hurricane Charley exposure and hazard of preterm delivery, Florida 2004. *Matern Child Health J* 2016; **20:** 2474–82.

81 Ngwese NM, Saito O, Sato A, Boafo YA, Jasaw G. Traditional and local knowledge practices for disaster risk reduction in northern Ghana. *Sustainability* 2018; **10:** 825.

82 Fahlberg A, Vicino TJ, Fernandes R, Potiguara V. Confronting chronic shocks: social resilience in Rio de Janeiro's poor neighborhoods. *Cities* 2020; **99:** 102623.

83 Marshall EM, Frazier P, Frankfurt S, Kuijer RG. Trajectories of posttraumatic growth and depreciation after two major earthquakes. *Psychol Trauma* 2015; **7:** 112–21.

84 Wind TR, Joshi PC, Kleber RJ, Komproe IH. The impact of recurrent disasters on mental health: a study on seasonal floods in northern India. *Prehosp Disaster Med* 2013; **28:** 279–85.

85 Goenjian AK, Najarian LM, Pynoos RS, et al. Posttraumatic stress reactions after single and double trauma. *Acta Psychiatr Scand* 1994; **90:** 214–21.

86 Matsuoka Y, Nishi D, Nakaya N, et al. Concern over radiation exposure and psychological distress among rescue workers following the Great East Japan Earthquake. *BMC Public Health* 2012; **12:** 249.

87 Garfin DR, Silver RC, Gil-Rivas V, et al. Children's reactions to the 2010 Chilean earthquake: the role of trauma exposure, family context, and school-based mental health programming. *Psychol Trauma* 2014; **6:** 563–73.

88 Garfin DR, Silver RC, Ugalde FJ, Linn H, Inostroza M. Exposure to rapid succession disasters: a study of residents at the epicenter of the Chilean Bío Bío earthquake. *J Abnorm Psychol* 2014; **123:** 545–56.

89 Shrira A, Palgi Y, Hamama-Raz Y, Goodwin R, Ben-Ezra M. Previous exposure to the World Trade Center terrorist attack and posttraumatic symptoms among older adults following Hurricane Sandy. *Psychiatry* 2014; **77:** 374–85.

90 Yabe H, Suzuki Y, Mashiko H, et al. Psychological distress after the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident: results of a mental health and lifestyle survey through the Fukushima Health Management Survey in FY2011 and FY2012. *Fukushima J Med Sci* 2014; **60:** 57–67.

91 Karz A, Reichstein J, Yanagisawa R, Katz CL. Ongoing mental health concerns in post-3/11 Japan. *Ann Glob Health* 2014; **80:** 108–14.

92 Palgi Y, Shrira A, Hamama-Raz Y, Palgi S, Goodwin R, Ben-Ezra M. Not so close but still extremely loud: recollection of the World Trade Center terror attack and previous hurricanes moderates the association between exposure to Hurricane Sandy and posttraumatic stress symptoms. *Compr Psychiatry* 2014; **55:** 807–12.

93 Kukihara H, Yamawaki N, Uchiyama K, Arai S, Horikawa E. Trauma, depression, and resilience of earthquake/tsunami/nuclear disaster survivors of Hirono, Fukushima, Japan. *Psychiatry Clin Neurosci* 2014; **68:** 524–33.

94 Caramanica K, Brackbill RM, Stellman SD, Farfel MR. Posttraumatic stress disorder after Hurricane Sandy among persons exposed to the 9/11 disaster. *Int J Emerg Ment Health* 2015; **17:** 356–62.

95 Ueda Y, Murakami M, Maeda M, et al. Risk factors for problem drinking among evacuees in Fukushima following the Great East Japan Earthquake: the Fukushima Health Management Survey. *Tohoku J Exp Med* 2019; **248:** 239–52.

96 Ueda Y, Yabe H, Maeda M, et al. Drinking behavior and mental illness among evacuees in Fukushima following the Great East Japan Earthquake: the Fukushima Health Management Survey. *Alcohol Clin Exp Res* 2016; **40:** 623–30.

97 Reifels L, Mills K, Dückers MLA, O'Donnell ML. Psychiatric epidemiology and disaster exposure in Australia. *Epidemiol Psychiatr Sci* 2019; **28:** 310–20.

98 Reifels L, Spittal MJ, Dückers MLA, Mills K, Pirkis J. Suicidality risk and (repeat) disaster exposure: findings from a nationally representative population survey. *Psychiatry* 2018; **81:** 158–72.

99 Orui M, Ueda Y, Suzuki Y, et al. The relationship between starting to drink and psychological distress, sleep disturbance after the Great East Japan Earthquake and nuclear disaster: the Fukushima Health Management Survey. *Int J Environ Res Public Health* 2017; **14:** 1281.

100 Bromet EJ, Clouston S, Gonzalez A, Kotov R, Guerrera KM, Luft BJ. Hurricane Sandy exposure and the mental health of World Trade Center responders. *J Trauma Stress* 2017; **30:** 107–14.

101 Stough LM, North CS. The association of adverse mental health effects with repeated exposure to disasters. *Ann Clin Psychiatry* 2018; **30:** 17–24.

102 Li J, Alper HE, Gargano LM, Maslow CB, Brackbill RM. Re-experiencing 9/11-related PTSD symptoms following exposure to Hurricane Sandy. *Int J Emerg Ment Health* 2018; **20:** 10.4172/1522-4821.1000404.

103 Nagamine M, Giltay EJ, Shigemura J, et al. Assessment of factors associated with long-term posttraumatic stress symptoms among 56 388 first responders after the 2011 Great East Japan Earthquake. *JAMA Netw Open* 2020; **3:** e2018339.

104 Nagamine M, Yamamoto T, Shigemura J, et al. The psychological impact of the Great East Japan Earthquake on Japan Ground Self-Defense Force personnel: a three-wave, one-year longitudinal study. *Psychiatry* 2018; **81:** 288–96.

105 Généreux M, Maltais D, Petit G, Roy M. Monitoring adverse psychosocial outcomes one and two years after the Lac-Mégantic train derailment tragedy (Eastern Townships, Quebec, Canada). *Prehosp Disaster Med* 2019; **34:** 251–59.

106 Gargano LM, Li J, Millien L, Alper H, Brackbill RM. Exposure to multiple disasters: the long-term effect of Hurricane Sandy (October 29, 2012) on NYC survivors of the September 11, 2001 World Trade Center attack. *Psychiatry Res* 2019; **273:** 719–24.

107 Catani C, Gewirtz AH, Wieling E, Schauer E, Elbert T, Neuner F. Tsunami, war, and cumulative risk in the lives of Sri Lankan schoolchildren. *Child Dev* 2010; **81:** 1176–91.

108 Suryana E, Nizamuddin N, Sabti A, Imran I, Syahrul S, Mawarpury M. An analysis of psychological trauma and depression of survivors in recurring disaster. *J Ilmiah Peuradeun* 2020; **8:** 531–51.

109 Hu MD, Lawrence KG, Gall M, et al. Natural hazards and mental health among US Gulf Coast residents. *J Expo Sci Environ Epidemiol* 2021; **31:** 842–51.

110 Shigemura J, Terayama T, Kurosawa M, et al. Mental health consequences for survivors of the 2011 Fukushima nuclear disaster: a systematic review. Part 1: psychological consequences. *CNS Spectr* 2021; **26:** 14–29.

111 Kusama T, Aida J, Sugiyama K, et al. Does the type of temporary housing make a difference in social participation and health for evacuees of the Great East Japan Earthquake and tsunami? A cross-sectional study. *J Epidemiol* 2019; **29:** 391–98.

112 Kunii Y, Suzuki Y, Shiga T, et al. Severe psychological distress of evacuees in evacuation zone caused by the Fukushima Daiichi Nuclear Power Plant accident: the Fukushima Health Management Survey. *PLoS One* 2016; **11:** e0158821.

113 Hayashi F, Sanpei M, Ohira T, et al. Changes in the mental health status of adolescents following the Fukushima Daiichi nuclear accident and related factors: Fukushima Health Management Survey. *J Affect Disord* 2020; **260:** 432–39.

114 Clemens SL, Berry HL, McDermott BM, Harper CM. Summer of sorrow: measuring exposure to and impacts of trauma after Queensland's natural disasters of 2010–2011. *Med J Aust* 2013; **199:** 552–55.

115 Benight CC. Collective efficacy following a series of natural disasters. *Anxiety Stress Coping* 2004; **17:** 401–20.

116 Sugiura M, Sato S, Nouchi R, et al. Eight personal characteristics associated with the power to live with disasters as indicated by survivors of the 2011 Great East Japan Earthquake disaster. *PLoS One* 2015; **10:** e0130349.

117 Mann CL, Gillezeau CN, Massazza A, et al. Fukushima triple disaster and the road to recovery: a qualitative exploration of resilience in internally displaced residents. *Psychiatr Q* 2018; **89:** 383–97.

118 Begg A, D'Aeth L, Kenagy E, Ambrose C, Dong H, Schluter PJ. Wellbeing recovery inequity following the 2010/2011 Canterbury earthquake sequence: repeated cross-sectional studies. *Aust N Z J Public Health* 2021; **45:** 158–64.

119 Afifi WA, Felix ED, Afifi TD. The impact of uncertainty and communal coping on mental health following natural disasters. *Anxiety Stress Coping* 2012; **25:** 329–47.

120 Muldoon OT, Acharya K, Jay S, Adhikari K, Pettigrew J, Lowe RD. Community identity and collective efficacy: a social cure for traumatic stress in post-earthquake Nepal. *Eur J Soc Psychol* 2017; **47:** 904–15.

121 Morgan J, Begg A, Beaven S, et al. Monitoring wellbeing during recovery from the 2010–2011 Canterbury earthquakes: the CERA Wellbeing Survey. *Int J Disaster Risk Reduct* 2015; **14:** 96–103.

122 Benight CC, Harper ML, Zimmer DL, Lowery M, Sanger J, Laudenslager ML. Repression following a series of natural disasters: immune and neuroendocrine correlates. *Psychol Health* 2004; **19:** 337–52.

123 Fernandez WG, Galea S, Miller J, et al. Health status among emergency department patients approximately one year after consecutive disasters in New York City. *Acad Emerg Med* 2005; **12:** 958–64.

124 Aldrich DP, Sawada Y. The physical and social determinants of mortality in the 3.11 tsunami. *Soc Sci Med* 2015; **124:** 66–75.

125 Mishra M, Acharyya T, Pattnaik N. Characterizing shifting pattern of disaster-induced death and disaster management policies: a regional analysis from Odisha, India. *Curr Sci* 2021; **120:** 1721–27.

126 Thamarapani D. Natural disasters and child health. *Environ Dev Econ* 2020; **26:** 1–19.

127 Hayashi F, Ohira T, Nakano H, et al. Association between post-traumatic stress disorder symptoms and bone fractures after the Great East Japan Earthquake in older adults: a prospective cohort study from the Fukushima Health Management Survey. *BMC Geriatr* 2021; **21:** 18.

128 Hahn MB, Van Wyck R, Lessard L, Fried R. Compounding effects of social vulnerability and recurring natural disasters on mental and physical health. *Disaster Med Public Health Prep* 2021; published online March 24. https://doi.org/10.1017/dmp.2020.476.

129 Satoh H, Ohira T, Hosoya M, et al. Evacuation after the Fukushima Daiichi Nuclear Power Plant accident is a cause of diabetes: results from the Fukushima Health Management Survey. *J Diabetes Res* 2015; **2015:** 627390–99.

130 Sakai A, Ohira T, Hosoya M, et al. Life as an evacuee after the Fukushima Daiichi nuclear power plant accident is a cause of polycythemia: the Fukushima Health Management Survey. *BMC Public Health* 2014; **14:** 1318.

131 Hashimoto S, Nagai M, Fukuma S, et al. Influence of post-disaster evacuation on incidence of metabolic syndrome. *J Atheroscler Thromb* 2017; **24:** 327–37.

132 Ohira T, Hosoya M, Yasumura S, et al. Effect of evacuation on body weight after the Great East Japan Earthquake. *Am J Prev Med* 2016; **50:** 553–60.

133 Tsubokura M, Takita M, Matsumura T, et al. Changes in metabolic profiles after the Great East Japan Earthquake: a retrospective observational study. *BMC Public Health* 2013; **13:** 267.

134 Peltan ID. Disaster relief and recovery after a landslide at a small, rural hospital in Guatemala. *Prehosp Disaster Med* 2009; **24:** 542–48.

135 Kodama Y, Oikawa T, Hayashi K, et al. Impact of natural disaster combined with nuclear power plant accidents on local medical services: a case study of Minamisoma Municipal General Hospital after the Great East Japan Earthquake. *Disaster Med Public Health Prep* 2014; **8:** 471–76.

136 Ochi S, Tsubokura M, Kato S, et al. Hospital staff shortage after the 2011 triple disaster in Fukushima, Japan—an earthquake, tsunamis, and nuclear power plant accident: a case of the Soso district. *PLoS One* 2016; **11:** e0164952.

137 Hirohara M, Ozaki A, Tsubokura M. Determinants and supporting factors for rebuilding nursing workforce in a post-disaster setting. *BMC Health Serv Res* 2019; **19:** 917.

138 Xue K, Guo S, Liu Y, Liu S, Xu D. Social networks, trust, and disaster-risk perceptions of rural residents in a multi-disaster environment: evidence from Sichuan, China. *Int J Environ Res Public Health* 2021; **18:** 2106.

139 Bustillos Ardaya A, Evers M, Ribbe L. What influences disaster risk perception? Intervention measures, flood and landslide risk perception of the population living in flood risk areas in Rio de Janeiro state, Brazil. *Int J Disaster Risk Reduct* 2017; **25:** 227–37.

140 Bacon CM, Sundstrom WA, Stewart IT, Beezer D. Vulnerability to cumulative hazards: coping with the coffee leaf rust outbreak, drought, and food insecurity in Nicaragua. *World Dev* 2017; **93:** 136–52.

141 Jedd T, Bathke D, Gill D, et al. Tracking drought perspectives: a rural case study of transformations following an invisible hazard. *Weather Clim Soc* 2018; **10:** 653–72.

142 Pauli N, Williams M, Henningsen S, et al. "Listening to the sounds of the water": bringing together local knowledge and biophysical data to understand climate-related hazard dynamics. *Int J Disaster Risk Science* 2021; **12:** 326–40.

143 Zhou W, Guo S, Deng X, Xu D. Livelihood resilience and strategies of rural residents of earthquake-threatened areas in Sichuan province, China. *Nat Hazards* 2021; **106:** 1–21.

144 Trias APL, Cook ADB. Future directions in disaster governance: insights from the 2018 Central Sulawesi earthquake and tsunami response. *Int J Disaster Risk Reduct* 2021; **58:** 102180.

145 Nukpezah JA. The financial and public health emergencies in Flint, Michigan: crisis management and the American federalism. *Risks Hazards Crisis Public Policy* 2017; **8:** 284–311.

146 Tagliacozzo S. Government agency communication during postdisaster reconstruction: insights from the Christchurch earthquakes recovery. *Nat Hazards Rev* 2018; **19:** 4018001.

147 Donahue A, Tuohy R. Lessons we don't learn: a study of the lessons of disasters, why we repeat them, and how we can learn them. *Homel Secur Aff* 2006; **2:** https://doi.org/10.1061/(ASCE)NH.1527-6996.0000283.

148 Juffermans J, Bierens JJ. Recurrent medical response problems during five recent disasters in the Netherlands. *Prehosp Disaster Med* 2010; **25:** 127–36.

149 Nohrstedt D, Mazzoleni M, Parker CF, Di Baldassarre G. Exposure to natural hazard events unassociated with policy change for improved disaster risk reduction. *Nat Commun* 2021; **12:** 193.

150 Lu Y, Xu J. The progress of emergency response and rescue in China: a comparative analysis of Wenchuan and Lushan earthquakes. *Nat Hazards* 2014; **74:** 421–44.

151 de Waal J, Vogel C. Disaster risk profiling in southern Africa: inventories, impacts and implications. *Nat Hazards* 2016; **84:** 1921–42.

152 Hillig Z, Connell J. Social capital in a crisis: NGO responses to the 2015 Nepalese earthquakes. *Asia Pac Viewp* 2018; **59:** 309–22.

153 Dumbuya B, Nirupama N. Disasters and long-term economic sustainability: a perspective on Sierra Leone. *Int J Disaster Resil Built Environ* 2017; **8:** 58–76.

154 Zhang H, Dolan C, Jing SM, Uyimleshi J, Dodd P. Bounce forward: economic recovery in post-disaster Fukushima. *Sustainability* 2019; **11:** 6736.

155 Aldrich DP, Ono Y. Local politicians as linking social capital: an empirical test of political behavior after Japan's 3/11 disasters. *Nat Hazards* 2016; **84:** 1637–59.

156 Ono Y. The perceptions of local political actors after natural disasters: the effect of Japan's 3/11 disasters on local politics. *Risks Hazards Crisis Public Policy* 2017; **8:** 335–55.

157 Aldrich DP. It's who you know: factors driving recovery from Japan's 11 March 2011 disaster. *Public Adm* 2016; **94:** 399–413.

158 He L, Dominey-Howes D, Aitchison JC, Lau A, Conradson D. How do post-disaster policies influence household-level recovery? A case study of the 2010–11 Canterbury earthquake sequence, New Zealand. *Int J Disaster Risk Reduct* 2021; **60:** 102274.

159 Brunson J. Maternal, newborn, and child health after the 2015 Nepal earthquakes: an investigation of the long-term gendered impacts of disasters. *Matern Child Health J* 2017; **21:** 2267–73.

160 Simons G. Projecting failure as success: residents' perspectives of the Christchurch earthquakes recovery. *Cogent Soc Sci* 2016; **2:** 1126169.

161 Matsuura S, Shaw R. Exploring the possibilities of school-based recovery and community building in Toni District, Kamaishi. *Nat Hazards* 2015; **75:** 613–33.

162 Fraser T, Aldrich DP, Small A, Littlejohn A. In the hands of a few: disaster recovery committee networks. *J Environ Manage* 2021; **280:** 111643.

163 Spoon J, Hunter CE, Gerkey D, et al. Anatomy of disaster recoveries: tangible and intangible short-term recovery dynamics following the 2015 Nepal earthquakes. *Int J Disaster Risk Reduct* 2020; **51:** 101879.

164 Titz A. Geographies of doing nothing—internal displacement and practices of post-disaster recovery in urban areas of the Kathmandu Valley, Nepal. *Soc Sci* 2021; **10:** 110.

165 Crawford G, Morrison C. Community-led reconstruction, social inclusion and participation in post-earthquake Nepal. *Dev Policy Rev* 2021; **39:** 548–68.

166 Spoon J, Gerkey D, Chhetri RB, Rai A, Basnet U, Hunter CE. Understanding short-term household recoveries from the 2015 Nepal earthquakes: lessons learned and recommendations. *Prog Disaster Sci* 2021; **10:** 100169.

167 Spoon J, Gerkey D, Chhetri RB, Rai A, Basnet U. Navigating multidimensional household recoveries following the 2015 Nepal earthquakes. *World Dev* 2020; **135:** 105041.

168 Jauhola M. Scraps of home. *Asian J Soc Sci* 2015; **43:** 738–59.

169 Sargeant S, Finlayson A, Dijkstra T, et al. The influence of the physical environment on self-recovery after disasters in Nepal and the Philippines. *Int J Disaster Risk Reduct* 2020; **50:** 101673.

170 Tashiro A, Nakaya T, Nagata S, Aida J. Types of coastlines and the evacuees' mental health: a repeated cross-sectional study in Northeast Japan. *Environ Res* 2021; **196:** 110372.

171 Kaluski DN, Ophir E, Amede T. Food security and nutrition—the Ethiopian case for action. *Public Health Nutr* 2002; **5:** 373–81.

172 Ray-Bennett NS. The role of microcredit in reducing women's vulnerabilities to multiple disasters. *Disasters* 2010; **34:** 240–60.

173 Lu Y, Xu D, Wang Q, Xu J. Multi-stakeholder collaboration in community post-disaster reconstruction: case study from the Longmen Shan Fault area in China. *Environ Hazards* 2018; **17:** 85–106.

174 Kachali H, Storsjö I, Haavisto I, Kovács G. Inter-sectoral preparedness and mitigation for networked risks and cascading effects. *Int J Disaster Risk Reduct* 2018; **30:** 281–91.

175 Mohammad L, Peek L. Exposure outliers: children, mothers, and cumulative disaster exposure in Louisiana. *J Fam Strengths* 2019; **19:** 4.

176 Kelman I. Connecting theories of cascading disasters and disaster diplomacy. *Int J Disaster Risk Reduct* 2018; **30:** 172–79.