Confronting an unfamiliar hazard: Tsunami preparedness in Tasmania

Douglas Paton, Mai Frandsen and David Johnston examine perceptions of risk of tsunami in Tasmania and discuss a US tsunami preparedness predictor model to see whether it might be useful in Tasmanian communities.

ABSTRACT

Recognition of the fact that Australian coastal communities can experience tsunami within hours of their being detected led to the development of the Australian Tsunami Warning System. If the benefits of this system are to be fully realized, members of communities susceptible to experiencing tsunami must be prepared to respond within this timeframe. This paper discusses how a lack of experience of tsunami hazards in communities in Tasmania that has resulted in low perception of risk being attributed to this hazard, with levels of preparedness being correspondingly low. The paper then discusses whether a model that has demonstrated an ability to predict preparedness in areas in the United States where tsunami risk is accepted can be applied in Tasmanian communities. Following demonstration that this model is not a good predictor when people are dealing with a hazard with low risk acceptance, an alternative model is presented and its utility evaluated. The role of planning and risk beliefs is also discussed.

Introduction

The December 24th 2004 Indian Ocean tsunami stimulated an unprecedented international effort to develop tsunami early warning capability, including the Australian Tsunami Warning System (Bird & Dominey-Howes, 2006; Geoscience Australia, 2007). This initiative is justified because northwest, northeast and eastern Australia face some 8,000 kilometres of active tectonic plate boundaries capable of producing tsunami which could reach its shores within two to four hours (Australian Bureau of Meteorology, 2008). The benefits accruing from this initiative have been demonstrated several times. Tsunami warnings were issued on April 2nd 2007, September 30th 2007, and 16th July 2009. The last two events generated small (25-30cm) tsunami in Tasmania. The warning system was also activated in response to the tsunami generated off Samoa on September 28th 2009.

Being able to issue warnings in a timely manner makes a significant contribution to managing risk. However, given that tsunami could reach Australian shores within hours, the effectiveness of any warning system is also a function of whether people are prepared (e.g., having an emergency kit, developing and practicing family response plans) and able to respond within the time frame afforded by the warning process (Bird & Dominey-Howes, 2006; Paton et al, 2008; Pincock, 2007).

If the benefits of the warning system are to be fully realised, facilitating people's preparedness to respond effectively is essential. This issue is examined here by testing a model that has been shown to predict preparedness in communities in which tsunami risk is accepted (Paton et al., 2008; Paton et al., 2009) using data from communities on the eastern seaboard of Tasmania.

Modelling tsunami preparedness

Full details of the model being tested here can be found in Paton et al. (2008). In summary, the model proposes that preparedness is the outcome of a process that commences with peoples' outcome expectancy beliefs (i.e., people's belief in the ability of the proposed mitigation actions to actually increase their safety). If people hold negative outcome expectancy beliefs (NOE), it is hypothesised that this reduces the likelihood of their preparing. If people hold positive outcome expectancy (POE) beliefs, their perception of receiving the resources needed to act (empowerment) is mediated by the social (involvement in community life, collective efficacy) processes used to articulate members' needs and expectations. Finally, the model proposes that trust (in civic sources of hazard and risk information) mediates the relationship between empowerment and preparing (see Figure 1). Preparation was assessed using a measure of tsunami preparedness proposed by Horikawa and Shuto (1983). However, given the prevailing low level of actual preparedness (see below), intention to prepare was used as the dependent variable.

This paper discusses two variables not included in the original model; planning and risk rejection. The planning measure was included because this

TABLE 1. Questionnaire Sections, Measures, Item Number and Scoring Range.

Measure	Adapted From	Item No.	Scoring Range
Risk Rejection	Paton et al. (2001)	4	1 (Strongly disagree) - 5 (Strongly agree)
Positive Outcome Expectancy	Bennet & Murphy (1997)	4	1 (Strongly disagree) - 5 (Strongly agree)
Negative Outcome Expectancy	Bennet & Murphy (1997)	4	1 (Strongly disagree) - 5 (Strongly agree)
Intention to Prepare	Paton et al., (2005)	5	1 (No), 2 (Possibly), 3 (Definitely)
Collective Efficacy	Zaccaro et al., (1995)	12	1 (Very Low) - 5 (Very High)
Empowerment	Speer & Peterson (2000)	4	1 (Not at all) - 5 (Always)
Trust	Dillon & Phillips (2001).	5	1 (Strongly disagree) - 5 (Strongly agree)
Community Involvement	Bishop et al., (2000)	10	1 (Strongly disagree) - 5 (Strongly agree)
Planning	Greenglass (2002)	14	1 (Not at all true) - 4 (Completely true)

variable has been implicated as a predictor of people's ability to take action to deal with environmental threats (Schwarzer, 2001). The risk rejection measure was included to examine whether a lack of belief in the ability of a hazard to pose a threat influenced preparedness behaviour. The specific hypotheses generated by the inclusion of these variables are discussed below.

Methods

Data were collected from communities (St Helens, Scamander, Orford, Lauderdale, Blackman's Bay, and Kingston) on the Tasmanian East coast. Only randomly selected households located at or below the 10 metres above sea level contour were targeted. This datum was selected to reflect the expected magnitude of a tsunami impacting Tasmania. Some 1000 Questionnaires were distributed in July and August 2008. The items comprising the questionnaire are described in Table 1. Data on gender, age, home ownership, and residence were also collected.

Because the model proposes that several independent variables interact to account for differences in levels of adoption of house protective measures, Structural Equation Model (SEM) was selected for the analysis. SEM can calculate multiple and inter-related dependence relationships simultaneously, allowing it to test the model as a whole and define how well the data fit (Goodness-of-Fit) the hypothesized model (Byrne, 2001).

While it was originally intended to use preparedness as the dependent variable, low levels of adoption of tsunami preparedness measures (see below) precluded this option. Intention to Prepare (which has proved a reliable predictor of preparing (Lindell & Whitney, 2000; Paton et al., 2005)) was thus treated as the endogenous (dependent) latent variable and Risk Rejection, Positive Outcome Expectancy, Negative Outcome Expectancy, Collective Efficacy, Community Involvement, Empowerment, Trust, and Planning as the exogenous (independent) latent variables. The items used to assess each of these constructs were considered as observed variables.

Results

Some 136 questionnaires were returned, giving a return rate of 13.6%. Gender was equally represented (50.7% male). The most common age bracket was 45-64 years (51.5%). Some 85% of participants owned their homes and 92 % lived permanently in the areas surveyed. The average number of years participants had lived in their current house and in the area was 12 and 18 years respectively.

Of the 136 questionnaires returned, fewer than 10 percent (deemed acceptable by Byrne, 2001) contained 'missing completely at random' data points and were replaced using the mean substitution method (Tabachnick & Fidell, 2007). The means, standard deviations, and ranges of the variables are listed in Table 2. An appraisal of histograms for skewness and kurtosis revealed that all variables were normally distributed. Inter-correlations between variables showed no evidence of multicollinearity or singularity. Inspection of scatterplots confirmed the linearity among latent variables. This also allowed for any outliers to be identified, of which there were none. Thus, the assumptions underlying SEM were upheld. Analysis was conducted (using AMOS 6), in two stages (Breckler, 1990). First the measurement model was tested to confirm that the measured variables did relate to the latent variables, and secondly, the structural models were tested to determine how well the theorised models fitted the data.

TABLE 2. Means, Standard Deviations, Cronbach's Alpha, and Range of Variables.

Variable	Mean	SD	Alpha	Range
Intention to Prepare	6.68	2.32	0.92	4-12
Collective Efficacy	12.26	3.87	0.96	4-20
Trust	11.74	3.71	0.89	4-20
Empowerment	9.55	3.09	0.86	4-18
Community Involvement	16.49	2.72	0.87	4-20
Risk Rejection	11.47	4.00	0.83	4-20
Positive Outcome Expectancy	12.40	3.91	0.76	4-20
Planning	12.66	1.93	0.79	8-17
Negative Outcome Expectancy	10.68	3.71	0.62	4-20

Note. SD = Standard Deviation

The measurement model

Confirmatory factor analysis (CFA) using AMOS 6 was used to determine if the observed variables adequately loaded on the eight latent variables. As recommended by Reisinger & Mavondo (2006), multiple fit indices were reported. The likelihood-ratio chi-square (χ^2) statistic is the primary measure of overall fit, and non-significant differences indicate a good fit of the model to the data. Because of the sensitivity of the chi squared statistic to sample size, Hu and Bentler (1999) recommend using the chi-square/df ratio (CMIN/DF). CMIN/DF ratios that are close to one suggest a very good model fit, while values < 2 indicate a good fit (Hu & Bentler, 1999; Reisinger & Mavondo, 2006). The Root Mean Square Error of Approximation (RMSEA) assesses the amount of error present in the fit and is considered to produce accurate assumptions about model quality, with values < 0.05 suggesting a good fit to the data, while values between 0.05-0.08 reflect an adequate fit (Reisinger & Mavondo, 2006). Values of the Comparative Fit Index (CFI) and Incremental Fit Index (IFI) greater than 0.95 are considered to reflect a good fit to the data (Reisinger & Mavondo, 2006; Streiner, 2006).

For the CFA analysis, the likelihood-ratio χ^2 test indicated that the observed data varied significantly from the model (χ^2 (433, n = 136) = 523, p = .002). However, with small samples, the calculated χ^2 may lead to inaccurate probability levels. Consequently, because they are least biased by sample size (Bentler, 1990; Hu & Bentler, 1998; Reisinger & Mavondo, 2006), the Comparative Fit (CFI) and Incremental Fit (IFI) indices were also used to assess the fit of the proposed model. Values over .95 indicate a good fit if the χ^2 is significant (Streiner, 2006). The obtained indices (CFI = .961, IFI = .962) indicate that the observed variables provided a good representation of the eight latent variables. A RMSEA of .039 and finding that the observed variables loaded significantly ($p < .01$) on their respective latent variables provided further support for the construct validity of the indicators (Streiner, 2006). Therefore, the variables used could be regarded as valid indicators and data analysis proceeded to test the structural models and to examine whether these variables could be used to predict tsunami preparedness.

The structural models

Three models were tested. Model 1 tested the original (Paton et al., 2008) model. Model 2 included the planning variable, and Model 3 added the risk rejection measure. In addition to the χ^2 value, the CMIN/df ratio is reported. Because of the sensitivity of the χ^2 statistic to sample size, Hu and Bentler (1999) recommend using the chi-square/df ratio (CMIN/DF). Ratios < 2 indicate a good fit (Hu & Bentler, 1999; Reisinger & Mavondo, 2006).

FIGURE 1. Summary of Model 1 Analysis (*p<0.05; ** p<0.01).

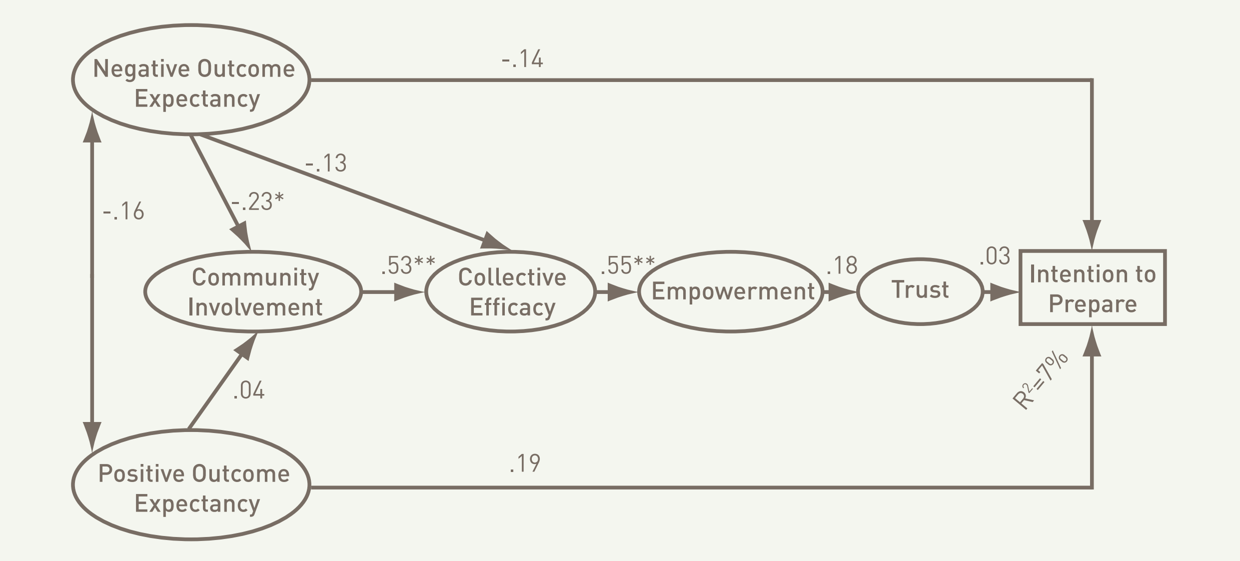


TABLE 3. Summary of Model Fit Indices for Proposed and Modified Structural Models.

Model	χ^2	p	CMIN/DF	RMSEA	RMSEA 90%	PCLOSE	CFI	IFI
Model 1	454.246	<.000	1.342	.052	.039-.064	.390	.942	.943
Model 2	386.968	<.04	1.141	.003	.009-.048	.971	.972	.973
Model 3	324.52	<.007	1.208	.039	.022-.053	.896	.968	.969

Model 1

For Model 1 (Figure 1), although the χ^2 value was significant, the CMIN/df ratio and the IFI, CFI, RMSEA and PCLOSE values indicated a moderate fit (Table 3). Nonetheless, its ability to account for only 7% of the variance in intention fails to provide support for it being a good predictor of tsunami preparedness.

The expected role of Trust (in civic source of risk/ hazard information) was not supported. The very poor relationship between trust and intention (Figure 1) suggests it is unlikely that this could be attributed to the small sample size. Although inconsistent with previous literature (e.g. Haynes et al., 2008; Paton et al, 2008), this could reflect tsunami not being recognised as a hazard (see below). Trust only becomes significant when a need to make decisions under conditions of uncertainty increases people's reliance on agencies to provide information (Paton, 2008). If a hazard is not recognized as such, people will not face uncertainty and thus have no need to evaluate the source of the information, making whether or not people trust a source irrelevant. This suggestion remains tentative until further research is undertaken.

Although Negative Outcome Expectancy and Positive Outcome Expectancy (Figure 1) did reveal relationships in the expected direction and with the expected sign, they just failed to reach significance. This could be attributed to the small sample size. Another tentative explanation is that, as a result of a general disbelief in the ability of tsunami to pose a threat in the areas surveyed (see below), people would not have had to think about the need for tsunami mitigation measures. As a consequence, they would have had no reason to consider whether mitigation measures would be effective. Since the outcome expectancy measures assess beliefs about the effectiveness of mitigation measures relative to the actions of a specific hazard, the lack of any need for people to have considered this question could account for a failure to find support for the hypothesised role of the outcome expectancy variables.

Model 2

Because 'planning' has been identified as a predictor of volitional behaviour (Sutton, 2008), a second objective was to expand the model by examining the role of planning. Planning was assessed using the planning subscale of the proactive coping inventory (Greenglass, 2002). It was originally hypothesised that planning would mediate the relationship between trust and intentions. However, because the Model 1 analysis indicated that trust did not play a significant role as a predictor, it was excluded and the analysis re-run using planning (Figure 2). This model provided a better fit to the data.

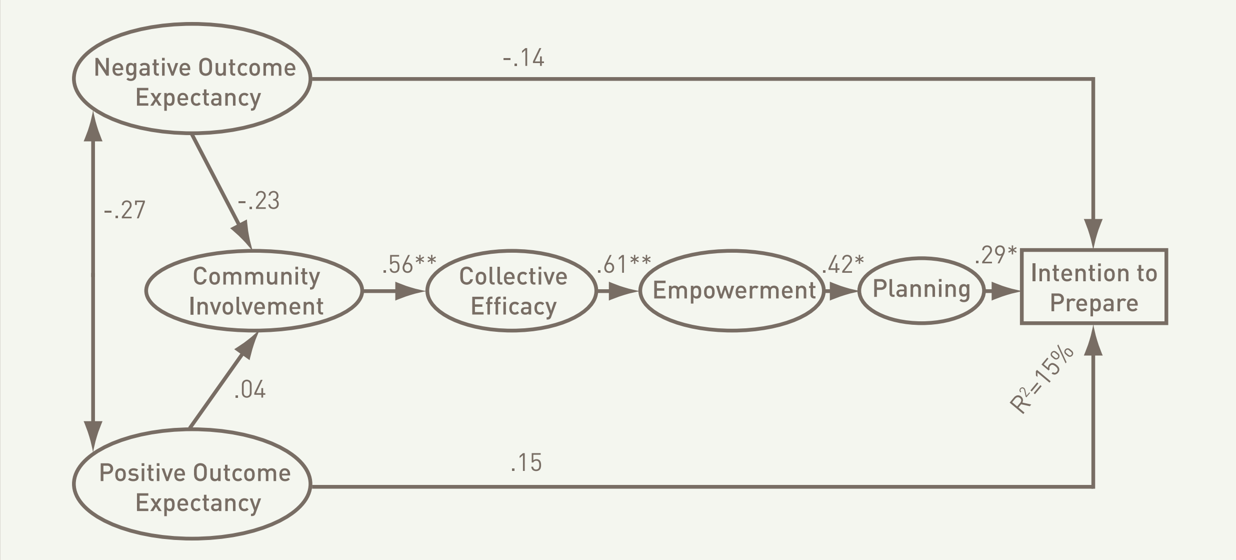
Although the χ^2 remained significant, the CMIN/df ratio and fit indices (Table 3) indicate that the data are a good fit to the model. Furthermore, this model accounted for 15% of the variance in intentions to prepare. While still relatively low, this was considerably better than Model 1. As with Model 1, the hypothesised paths for NOE and POE just failed to reach significance (see possible explanations offered above). This analysis offered support for the value of planning as a predictor. The final model examined how risk beliefs influenced intention to prepare.

Examining tsunami preparedness in Australia is complicated by tsunami not generally being recognised as a hazard (Frandsen, 2008). Frandsen interviewed residents in Tasmanian coastal communities about tsunami preparedness. She found that only 1 of 29 people (3%) interviewed believed that tsunami posed a risk to their community. The reasons people offered to account for their belief that tsunami did not pose a risk to Tasmanian coastal communities included their being unaware of any history of tsunami in the area, the lack of apparent causes of tsunami in the area making it unlikely that a tsunami could occur in their location, and no experience or evidence to suggest that a risk existed. If people do not perceive a risk, they are unlikely to prepare. Indeed, in the present study, only 15% of respondents had adopted any preparedness measures (and the preparedness measures that were in place had often been adopted to prepare for hazards such as storm surges rather than tsunami per se).

Model 3

The Risk Rejection measure (Paton et al., 2001) asked respondents to indicate the extent to which they agreed with questions such as 'the location of tsunami will be far from here' and 'the likelihood that tsunami will occur here has been exaggerated.' The higher the score, the less people perceive risk from a specific hazard. Based on work on factors influencing the adoption of protective actions in the health literature, it was hypothesised that an inverse relationship would exist between Risk Rejection and Intentions (Schwarzer, 2001). This hypothesis was supported. However, the modification indices produced for the Model 3 analysis suggested an alternative model. The data were a good fit to the model (Table 3) and accounted for 26% of the variance in intention (Figure 3).

FIGURE 2. Summary of Model 2 Analysis (*p<0.05; ** p<0.01).



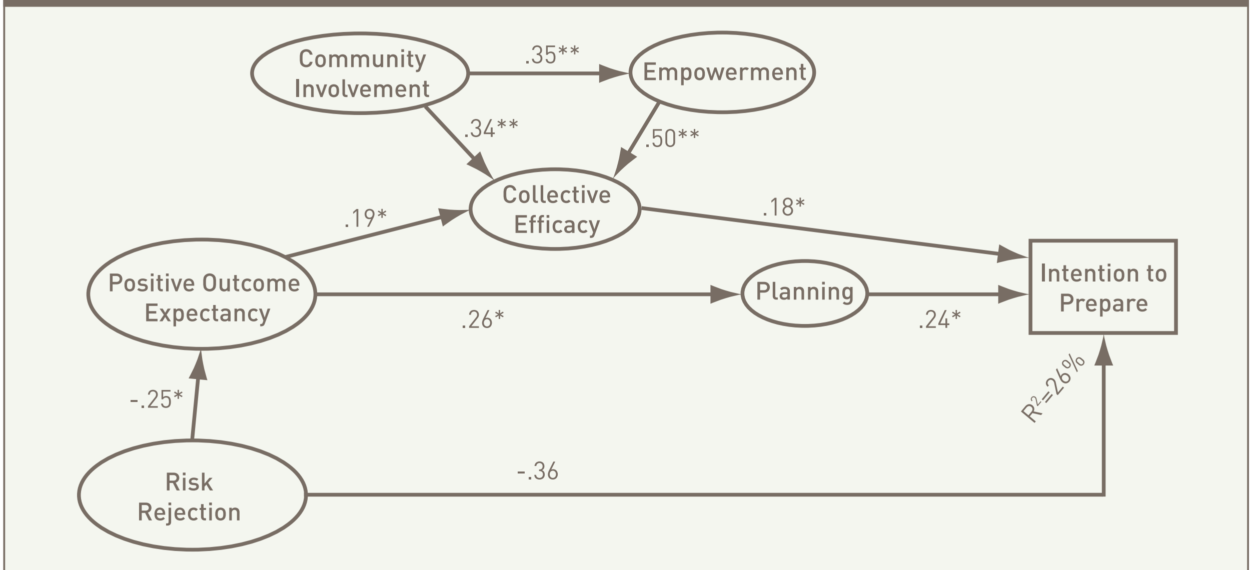
Discussion

The proposed model (Paton et al., 2008) did not provide a good fit to the data. The exclusion of trust and the inclusion of 'planning' and 'risk rejection' variables increased both model fit and its ability to account for differences in levels of intention to prepare for tsunami. Model 3 identified paths not anticipated in the original model.

It is possible that alternative models can be identified which fit the data better than, or as well as, the original model (Reisinger & Mavondo, 2006). Model 3 retains the basic relationship between personal (e.g., POE, risk rejection) and social context factors, but differs from the original (Paton et al., 2008) in that they played relatively more independent roles in the process. Because the specific arrangement of variables in Model 3 (Figure 3) was derived from the modification indices furnished by the SEM analysis, it is important to justify the observed relationships theoretically if a discussion of their implications is to be warranted.

A relationship between community connectedness and collective efficacy has been observed (Hobfoll et al., 2002; Sampson, Raudenbach & Earls, 1997) and several reviews (Dalton, Elias & Wandersman, 2007; Wandersman & Florin, 1990) identified a relationship between empowerment and collective efficacy and between involvement in community life and empowerment. In addition to providing a theoretically robust platform to discuss the revised model, the importance of confirming a role for community involvement, collective efficacy and empowerment derives from the key role these factors play as predictors of both risk beliefs (Lion, Meertens, & Bot,

FIGURE 3. Summary of Model 3 Analysis (*p<0.05; ** p<0.01).



2002; Siegrist & Cvetkovich, 2000) and the measures people take to mitigate risk (McGee & Russell, 2003; Paton et al., 2005).

The analyses provided support for Planning as a predictor of intentions, indicating that planning increases the likelihood that people will convert beliefs in the efficacy of preparing (POE) into a commitment to act (Gollwitzer, 1999). Model 3 provided partial support for the suggestion that high risk rejection (or low risk acceptance) could influence outcome expectancy beliefs. The negative relationship between risk rejection and POE (Figure 3) suggests that the less risk is attributed to a hazard, the less likely it is that people need to make judgements about whether mitigation measures are effective (which is what POE assesses), reducing the role of outcome expectancy in the process.

Conclusion

The small sample size may have reflected the low salience of tsunami hazards. If people do not believe that tsunami could pose a threat to them, they are less likely to respond to a survey on this topic. However, because the covariances which underlie SEM are sensitive to small sample size it had implications for the analysis. To accommodate this, fit indices considered least biased (CFI and IFI) were used to test model fit (Bentler, 1990; Hu & Bentler, 1998).

While the role of the hypothesised variables was supported, the relationships between them differed somewhat from those proposed in the original model (Paton et al., 2008). The hypothesised role for negative outcome expectancy was not supported and the roles of community involvement and empowerment were mediated by collective efficacy. The finding of a direct and indirect role for risk beliefs was novel. The possibility of these relationships resulting from the lack of familiarity with the hazard was discussed.

The analyses provide a basis for developing hypotheses for predicting tsunami preparedness in coastal communities in Australia that do not have a history of confronting this hazard. The findings highlight the importance of including community competencies and developing acceptance of the risk posed by tsunami in the public education component of tsunami risk management strategies. That is, facilitating hazard preparedness is not just about making information available to people. It is also about ensuring that community members have access to the social networks that influence the development and enactment of their risk beliefs (e.g., community involvement, community participation), the competencies (e.g., collective efficacy) required to identify how to respond to infrequent, uncertain events, and the ability to identify how to put strategies into action (e.g., planning). This work highlights a need for the community preparedness elements of risk management to be based on community engagement principles and integrated with community development strategies.

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