



## Assessment of households' responses to the tsunami threat: A comparative study of Japan and New Zealand



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### ABSTRACT

This study examines households' immediate responses to the potential for tsunami generated by 2011 earthquakes in New Zealand and Japan. Surveys conducted in Christchurch, New Zealand and Hitachi, Japan investigated pre-impact tsunami hazard communication, immediate post-impact expectations that these earthquakes would cause tsunamis, the information sources that respondents used after the shaking stopped, and household evacuation in anticipation of a tsunami. The results reveal some similar patterns as well as some significant differences in the ways that households in the two cities reacted to the tsunami threat. The results show that both cities had very low levels of pre-impact tsunami hazard communication and, possibly as a result, about half of the respondents significantly underestimated tsunami arrival times. Moreover, face-to-face conversation and telephone were the most important sources of disaster information in both communities after the shaking stopped. However, Hitachi households had a higher level of tsunami risk perception, expected sooner tsunami arrival times, and were more likely to evacuate than Christchurch households. Regression analyses indicate that risk perception was the only significant predictor of evacuation and Hitachi location, which was probably a proxy for shaking duration, was the only significant predictor of risk perception. However, these regression equations accounted for little variance, so further research is needed to better understand the tsunami evacuation process.

### 1. Introduction

The 2004 Indian Ocean tsunami killed approximately 250,000 people and caused an economic loss estimated at \$9.9 billion throughout the Indian Ocean basin [59]. One consequence of this event was to increase coastal residents' awareness that violent earthquake shaking might be their only source of warning about an imminent tsunami threat. Indeed, many residents of American Samoa recognized that their September 29, 2009 earthquake could cause a tsunami, so they evacuated their homes before the first wave arrived [44]. Many studies have identified variables that are relevant to people's response to tsunami threat, but few of them have explored the joint effects of multiple variables on tsunami evacuation. To bridge this gap, this study examines the relationship of tsunami risk perception, tsunami risk information sources, tsunami hazard awareness, and demographic

characteristics with tsunami evacuation in the immediate aftermath of earthquakes in Christchurch, New Zealand and Hitachi, Japan. In New Zealand, although a tsunami was not generated in Christchurch, the earthquake's shaking intensity in the city's tsunami at-risk locations exceeded the threshold at which the community had been told to evacuate. In addition, the earthquake shaking intensities for both Christchurch (M 6.3) and Hitachi (M 6+) were quite similar even though Hitachi was 300 km (187 mi) from the earthquake epicenter. Although earthquake was not a new type of hazard for Christchurch and Hitachi, tsunami events are rare for both locations. At the time of the 2011 earthquake, Hitachi residents had not experienced a significant tsunami since 1987 [25] and the most recent one to strike Christchurch occurred in 1960. Therefore, it is likely that few, if any, residents in Hitachi and Christchurch had tsunami evacuation experience before their 2011 earthquakes. Therefore, to better understand how people

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respond to this infrequent hazard, this article will examine residents' perceptions of, and responses to, tsunami threat, as well as the associations these variables have with each other and with demographic variables.

## 2. Literature review

### 2.1. Tsunami evacuation

Evacuation is the most common protective action in response to a hazard that provides some degree of forewarning [57]. In addition, Mas et al. [46] confirmed that evacuation is the most important and effective method to save human lives during a tsunami. In research on the 2010 Chile  $M_w$  8.8 earthquake and tsunami, Esteban et al. [13] found that the majority of coastal residents (about 60%) decided on their own to evacuate to surrounding hills immediately after the shaking stopped because the local authorities failed to issue a tsunami warning alert even though a tsunami warning system existed. These researchers also found that, although residents were advised not to use vehicles for evacuation in some areas during the 2011 Japan  $M_w$  9.0 earthquake and tsunami, most of them still used their cars to evacuate. The excessive traffic demand caused serious traffic jams and, in turn, increased mortality during the evacuation.

In research on the 2004 Sumatra Indonesia  $M_w$  9.0 earthquake and tsunami, Gregg et al. [22] reported that 89% of their respondents recognized the need to evacuate and, among those who did evacuate, almost two-thirds had to run to escape the oncoming waves. Another study of that tsunami reported that the first tsunami wave arrived 19.1 min after the earthquake [29] and that 43.1% of their survey respondents in Banda Aceh evacuated an average of 6.3 min before tsunami arrival, with 47.7% of the evacuees leaving because they saw a tsunami wave. Among 65 respondents, 48 (73.8%) were caught by the tsunami but survived by finding floating objects (29.3%), climbing onto house roofs (25%), swimming to safety (12.5%), climbing trees (12.5%), or taking other actions (15.4%).

Lindell et al. [44] study of 262 residents' evacuations from the 2009 American Samoa earthquake and tsunami showed that most people in the relatively flat southern part of the island used their own cars to evacuate (53.8%), followed by foot (17.9%), peer's cars (15.8%), public transportation (9.8%), and emergency vehicles (2.7%). Almost nobody evacuated to a higher floor (< 1%). These researchers found that only 4.8% of their respondents reported being caught by the tsunami which is quite different from the 73.8% of Iemura et al.'s [29] respondents who were caught by the 2004 Indian Ocean tsunami and might be due to the Samoans being able to feel the shaking and many of them knowing that this was an environmental cue to tsunami onset. Finally, people evacuated sooner if they resided in the coastal villages.

In another study of the 2009 American Samoa earthquake and tsunami, Apatu et al. [2] found that all (67%) or part (19%) of the households in the mountainous western and northern parts of the island evacuated by foot (74.4%) rather than car (15.9%), peer's cars (9.7%), public transportation (3.9%), and emergency vehicles (1.9%). Evacuation was positively related to shoreline proximity and household income.

### 2.2. Tsunami risk perception

Risk perception can be defined as the "certainty, severity, and immediacy of disaster impacts to the individual, such as death, property destruction and disruption of work and normal routines" ([41], p. 127). Disaster researchers have discovered that risk perception is an important predictor of people's responses to earthquakes, floods, hurricanes, tornadoes, and volcanic eruptions ([17,26,41,42,65], in press). Also, the importance of risk perception has been recognized by a number of hazard studies using the variables of expected property damage, casualties, job disruption, and service disruption to assess

people's risk perception [27,28,45,52,62].

Only one tsunami study reported correlations of risk perception with demographic variables [44]. In their study of 2009 American Samoa earthquake and tsunami, these researchers found that six risk perception variables (tsunami expectation, expected tsunami arrival time, expected Samoa casualties and property damage, and expected personal casualties and property damage) were positively correlated with homeownership and hazard awareness (earthquake meeting and brochure; and tsunami brochure), and were negatively correlated with household size, community tenure, and information sources (e.g., face-to-face; phone/text; and radio/TV).

Correlates of risk perception have also been identified in studies of earthquake response. A study of immediate response to earthquake shaking in Christchurch New Zealand and Hitachi Japan reported that risk perception was most strongly correlated with perceived shaking intensity but also had small correlations with female gender, marital status, household size, education, and income [45]. In a study of response to the Umbria-Marche earthquake, Prati et al. [54] reported that women were slightly more likely than men to report fear during the shaking, findings that were also reported in a 1987 Whittier Narrows earthquake study in Southern California [20], and Goltz's [20] review of data from three California earthquakes. Moreover, Lindell et al. [44] found that female gender is correlated with risk perception but not correlated with fear (emotion). In addition, Goltz [20] found that fear was also correlated with Hispanic ethnicity, lower education, shorter California tenure, greater perceived shaking intensity, presence of children during shaking, and feeling unprepared for an earthquake.

Finally, research on other hazards has demonstrated that risk perception is significantly correlated with demographic characteristics such as household size [44], homeownership [44], tenure [44,52], age [23,24,5], female gender [15,38,47,60], and lower education and income [16,38,55].

### 2.3. Post-impact information sources

Effective tsunami risk communication has been highlighted by previous studies. Lindell and Prater [43] emphasized that tsunami risk communication research should examine the channels and messages that coastal residents prefer to use for receiving warnings, assess the effectiveness of different channels/messages, and explore how accessible different population segments are to different communication channels. More recently, Pararas-Carayannis [49] contended that "mass media can play a very important role in creating continuous awareness of potential threats and in achieving effective preparedness for tsunami and other marine hazards and thus minimize future losses of lives and destruction of property" (p. 70). People who live in hazard prone areas obtain hazard information from peers, local and national news media, newspapers, public authorities, Internet, Facebook, and Twitter, etc.

During the 2004 Indian Ocean tsunami, Perry [53] found that people in Mauritius—thousands of miles away from earthquake shaking—were most commonly warned by TV (51.4%), followed by radio (27.6%), face-to-face contact (15.4%), telephone (4.7%), and newspaper (.9%). By contrast, research on 2009 American Samoa earthquake and tsunami by Lindell et al. [44] found that 42.5% of the respondents recognized that earthquake shaking was a cue to tsunami arrival; most of the others were warned by radio (14.9%), village bells ringing (14.2%), face-to-face warnings (6.5%), telephone/text (4.2%), or social cues (10.3% saw others evacuating). In two studies of flash floods, Wu and his colleagues (in press) found that Colorado households were warned by observing rising water (40%), radio/TV (18%), peers (12%), and Internet (2%) during their 2013 flash flood. By contrast, households in Uttarakhand India were warned by peers (46%), observing rising water (46%), and authorities (7%) in their 2013 flash flood.

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