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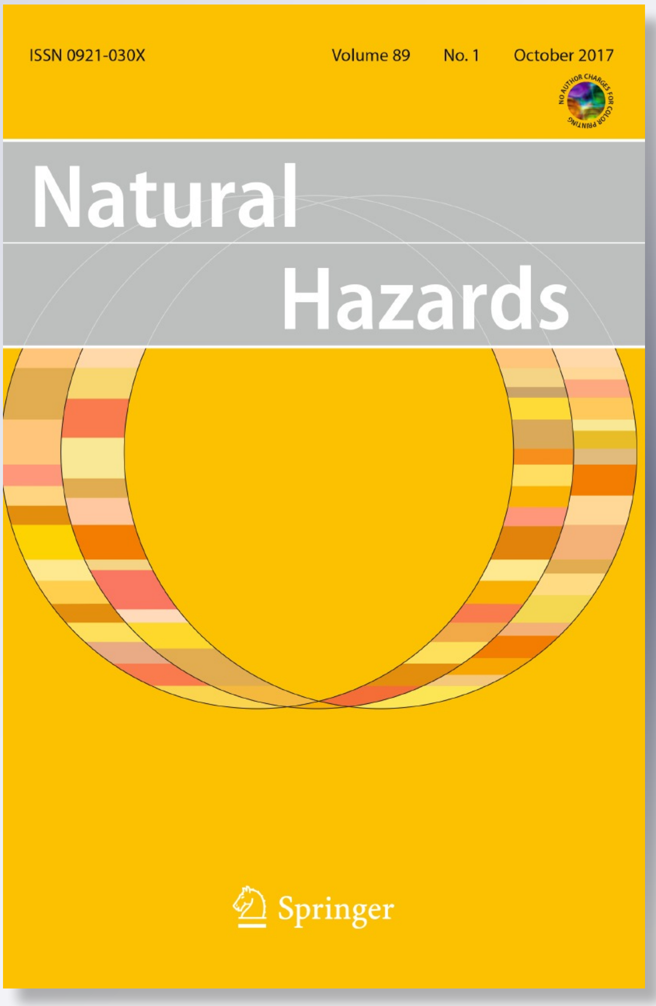

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ORIGINAL PAPER

Awareness of tsunami natural warning signs and intended evacuation behaviors in Java, Indonesia

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Abstract The south coast of Java has a long history of deadly seismogenic tsunamis. The most recent tsunami events in 1994 and 2006 killed hundreds due to lack of awareness and implementation of disaster mitigation strategies. Community-based tsunami hazard education programs founded on observation of natural warning signs and self-evacuation are critical to saving lives. Students at middle and high schools in three cities along the southern coast of Java ($N = 887$) participated in a pen/paper survey that included critical awareness, risk perception, self-efficacy, response efficacy, evacuation intentions, past participation in evacuation simulations, communication channels, and warning preferences. Participants generally had high perceived tsunami risk and efficacy. Overall, participants who associated tsunamis with earthquakes know that a receding ocean is a sign of an impending tsunami and believed that vertical evacuation was more important than inland evacuation. School, Internet, and social media were most often reported as information sources. However, the majority of participants believed that an earthquake had to be dramatic to cause a tsunami. Participants overestimated both the duration of ground shaking prior to a tsunami event and the suggested evacuation window. Differences between cities were found for evacuation simulation history and personal experience with tsunamis; however, neither increased critical awareness. Evacuation simulations, coupled with education of under what circumstances to evacuate (20/20/20 principle), should be implemented throughout Java. Short messages stressing that even weak earthquakes can

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cause tsunamis should be communicated through a variety of channels such as TV, radio, Internet, and social media.

Keywords Tsunami · Preparedness assessment · Disaster mitigation · Community education · Preparedness interventions · Java · Indonesia · Public health · Warnings · Risk perception · Critical awareness · Efficacy perception · Evacuation

1 Background

1.1 2004 Indian Ocean tsunami

The 2004 mega-tsunami that struck the Indian Ocean region was a wake-up call for the disaster mitigation community. Geoscientists studying the history of earthquakes and tsunamis in the region forecasted the event (Newcomb and McCann 1987; Harris and Prasetyadi 2002; Ortiz and Bilham 2003), but little of this research was disseminated to those in harm's way, and little to nothing was done to increase tsunami hazards resilience on the coast of Sumatra and other areas further from the epicenter (Harris 2016). In total, over 280,000 lives were lost (Lay et al. 2005).

This unequaled tsunami disaster calls for an emphasis on the importance of strengthening both the "hard" and "soft" aspects of tsunami disaster mitigation by empowering those most threatened by natural hazards to build resiliency to these hazards. Within 2 weeks of the 2004 tsunami, the American Geophysical Union (AGU) published a statement addressing the need for broadening the responsibility of the geoscience community for all aspects of natural disaster prevention. The statement calls for the following: "(1) fundamental research on Earth and space, and monitoring of natural hazards; (2) dissemination of the relevant results to the public, especially vulnerable communities; and (3) implementation of multidisciplinary efforts needed to apply effective mitigation strategies worldwide" (Sorooshian 2005, p. 14).

This statement articulated the responsibility of geoscientists to not only conduct more research on forecasting and monitoring geological hazards, but spearhead collaborative efforts with experts in a wide variety of fields to strengthen tsunami preparedness. Effective behavior change strategies should include assessment of current knowledge levels, implementation of culturally tailored mitigation strategies, and evaluation and refinement of efforts (Edberg 2013). This paper, a collaborative effort between public health and geoscience experts, focuses on theory-based assessment of current knowledge levels in coastal areas of Java, Indonesia.

1.2 Present risk in Java, Indonesia

There are approximately 4.35 million Indonesians imperiled by tsunamis along the southern coasts of Sumatra, Java, and Bali. These individuals may have as little as 20 min to reach safe high ground (Post et al. 2009). Due to its high population density and many low-lying, coastal communities, the south coast of Java, in particular, is one of the most at-risk areas in Indonesia (Fig. 1) and has a long history of deadly seismogenic and volcanogenic tsunamis (Wichmann 1918, 1922; Harris and Major 2016). Of note is the high rate of earthquakes and tsunamis that struck Java in the mid-nineteenth and twentieth

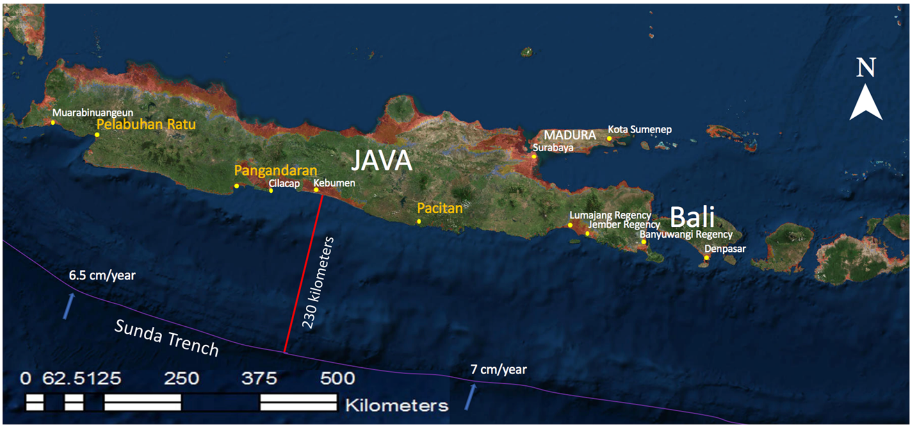

Fig. 1 ArcGIS elevation map with *red overlay* showing topographic areas less than 30 m above sea level. The Sunda Trench, located roughly 230 km to the south, is drawn in *purple* and plate movement vectors in *blue*. Several major cities are shown by *yellow dots*. There are over 1 million people living in coastal communities along the southern coast at less than 15 m above sea level. Many of these coastal towns have concave coastal topography that could amplify tsunami run-up height and risk. Tsunami awareness surveys were performed at Pelabuhan Ratu, Pangandaran, and Pacitan

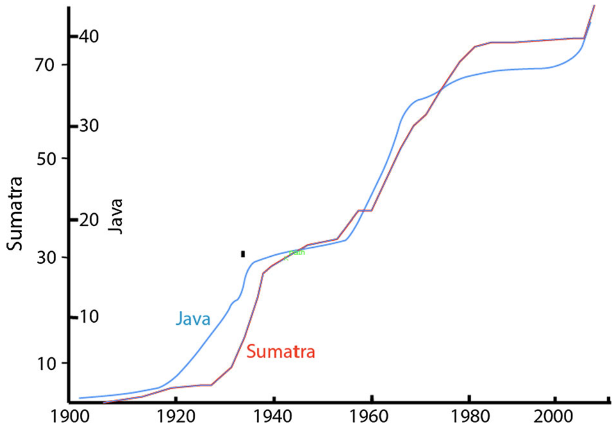

Fig. 2 Cumulative number of earthquakes (>magnitude 6) through time from 1900 to 2010 in Java and Sumatra. Note the three distinct periods of seismic quiescence. The population of Sumatra and Java increased by an order of magnitude during the past two periods of seismic quiescence. The end of the last period of quiescence in 2004 started an earthquake storm that may last for another 20–30 years

centuries. The west coast of Java was destroyed by a tsunami from the 1883 eruption of Krakatoa and accompanying caldera collapse that triggered tsunami wave heights up to 37 m (120 ft), killing more than 36,400 people (Pararas-Carayannis 2003). More recently, tsunami earthquakes south of Java, such as the 1994 7.8 Mw event south of East Java and the 2006 7.7 Mw event south of Pangandaran, have killed hundreds in low-lying coastal communities.

The last 100 years of major earthquake (>magnitude 6) recordings by the USGS indicate that Java underwent three alternating intervals of earthquake quiescence followed by increased seismic activity, with the last interval ending in 2004 (Fig. 2). The pattern of seismicity shown in Fig. 2 indicates that the Java Trench plate boundary accumulates potential slip at a rate of 7 cm/year for periods of 30–40 years, which are followed by another 30–40 years of larger and much more frequent earthquake events—an earthquake storm. The most recent earthquake storm initiated in 2004. However, only a small fraction of the slip that accumulated during the past 40 years of seismic quiescence has been released, meaning it is highly likely that the Java region will experience a major, tsunami-generating earthquake sometime in the near future.

No major tsunamis had struck the Sumatra region for over 150 years before the magnitude 9.2 megathrust earthquake and mega-tsunami claimed >180,000 lives there. This lack of activity prior to a giant earthquake and tsunami event is common and is likely to happen in Java similarly to what happened in 2004 in Sumatra. Historical records indicate there has not been a giant earthquake-tsunami in Java for at least 430 years (Harris and Major 2016). During this time, around 28 m of potential slip has accumulated that, if it released all at once, as in Sumatra, will produce a giant earthquake and tsunami.

Even though the 2004 Sumatra tsunami was one of the largest ever recorded, the death toll was uncommonly high due to a lack of tsunami hazards awareness. In contrast, the 2011 tsunami in Japan was around the same size as the Sumatra event, and affected a similar number of people, but claimed <20,000 lives. Japan has taken great care to increase preparedness against natural hazards over a long period of time (Suppasri et al. 2015). The sounding of the Early Warning System, the country's strict seismic building codes, and Japan's dedication to community education and preparedness activities contributed to a much lower death toll (Mimura et al. 2011). Thus, this order of magnitude difference in survivability is attributed mostly to differences in awareness of tsunami hazards and rapid implementation of disaster mitigation strategies. Community-based disaster mitigation in Japan had strengthened 'soft measures' through organizing workshops, disaster education, and evacuation measures, including dissemination of tsunami hazard maps to every household. Around 3000 schoolchildren were able to successfully evacuate in Kamaishi based on ground shaking and prior to instruction by local authorities and evacuation alerts (Mimura et al. 2011). This comparison between Japan and Sumatra underscores the critical role of strengthening tsunami disaster mitigation through communication campaigns, community education, and preparedness interventions.

1.3 Current efforts and challenges

Natural disaster preparedness can be implemented at the institutional level (e.g., investment of authorities) or citizen level (e.g., individual preparation measures) (Esteban et al. 2013). After the 2004 tsunami event, several preparedness "hard measures" were implemented throughout Indonesia at the institutional level, most notably the Indonesian Tsunami Early Warning Systems (InaTEWS) and placement of tsunami evacuation and warning signs which are found throughout coastal areas of Java. There are several challenges to these top-down approaches, including gaps in knowledge and implementation that may stymie the ability of these institutional measures to succeed in the event of a tsunami, requiring further interventions at the citizen level. The foremost challenge to engineering and effectively implementing the InaTEWS for Java is its nearby distance to the Java Trench (Lauterjung et al. 2010). Additional problems involve lack of national guidance, public understanding of and trust in the system (Spahn et al. 2010) and a lack of communication infrastructure for relaying tsunami warnings to coastal populations.

Strunz et al. (2011) argue that Early Warning Systems (EWS) should integrate four elements: "(1) the knowledge of the risks, (2) the technical monitoring and warning service, (3) the dissemination and communication of meaningful warnings to those at risk, and (4) the public awareness and preparedness to react to warnings" (p. 67). Accordingly, even if warning systems were technically reliable, without knowledge and efficacy to react to the warnings, there could still be significant loss of life. According to the Badan Meterologi Klimatalogi dan Geofisika of Indonesia (2010), several hundred people were killed during the 2010 Mentawai tsunami after an early warning generated by the system failed to reach isolated coastal communities, thus demonstrating that reliance on the technical ability of the EWS to effectively warn the population could result in unnecessary loss of life. An additional challenge faced by EWS is when to terminate the warning after the initial alarm. For example, during both the Mentawai (2010) and Japan (2011) tsunami, warnings were terminated prematurely although tsunamis were still occurring hours later (Suppasri et al. 2015). A shortcoming of this model is that even if EWS works as intended, the mitigation strategy relies mostly on top-down dissemination of warnings heavily reliant on national institutions. This focus fosters dependency and is likely to fail and/or delay evacuation.

The placement of tsunami evacuation signs throughout Java is another effort implemented at the institutional level. These signs typically include an arrow in the direction of evacuation and an image of a steep wave with an individual running uphill away from the wave. This effort has likely increased awareness of uphill evacuation. However, information about *under what circumstances* to evacuate is lacking from the signage. If people fail to recognize natural warning signs or evacuate too late to reach safe ground in time, current efforts alone will be insufficient to prevent disaster. Additionally, Cox (2001) argues that the depiction of steep tsunami waves in such images are likely to create a false impression of incoming tsunamis, whereas tsunamis approaching shore are often perceived as gradual rises and falls in water level rather than a distinguishable wave. Cox argues that "failure to realize that tsunami waves often have such small steepness that they cannot be recognized as waves has undoubtedly contributed to the loss of life associated with tsunamis" (p. 92). These institutional efforts should be accompanied by increased education and knowledge of natural warning signs, the nature of tsunamis, and evacuation protocol at the citizen level.

1.4 Response capabilities and preparedness

Sullivan and Häkkinen (2006) argue that the level of study put into physical science disaster research should be accompanied by research that seeks to understand the psychological elements behind the human response to disaster. Response capabilities consist of three main points: "warning dissemination (do people receive and understand the warning?), anticipated response (do people respond to warnings and evacuate?) and evacuation (are people able to reach safe areas on time?)" (Strunz et al. 2011, p. 72). Factors such as low risk perception are likely to decrease evacuation response speed (Dash and Gladwin 2007). Several of these critical factors can be addressed through community education campaigns. Considering past failures of the InaTEWS, educational efforts stressing observation of natural warning signs and self-evacuation are critical to quick warning dissemination and response.

This paper offers an assessment of tsunami hazard awareness, risk and efficacy perceptions, and preparedness in schools along the southern coast of Java. We conducted surveys to determine baseline perceptions of tsunami risk and efficacy, tsunami causes and warning signs, previous participation in evacuation simulations, perceptions of when and how to evacuate, evacuation intentions, communication channels, and warning preferences.

Results of this survey can be used to address knowledge gaps and design appropriate community-level interventions.

2 Methods

2.1 Survey development

We developed a 20-question survey based on several relevant preparation model constructs that have been previously applied to tsunami preparedness (Paton 2003; Johnston et al. 2005). Constructs included risk perception, self-efficacy, response efficacy, critical awareness, and evacuation intentions. We also included questions about history of participation in evacuation simulations, communication channels, and warning preferences. Lastly, we asked basic demographic questions to account for any differences in demographic distribution between our three study sites. Surveys were created in English and independently translated by three individuals fluent in both English and Bahasa Indonesia. Discrepancies in word choices were resolved by agreement between the three translators. Surveys were pretested on Indonesian geology students from the Universitas Pembangunan Nasional (UPN). The final surveys were conducted in Bahasa Indonesia.

Risk perception of floods, earthquakes, and tsunamis were assessed on a 1–5 Likert scale from "strongly disagree" to "strongly agree." Perceptions of ability to save oneself in the event of a tsunami were likewise assessed on a 1–5 scale. Awareness questions included knowledge of what can cause a tsunami as well as specific recommendations created based on our geologic modeling of the area. We used GeoClaw (LeVeque et al. 2013) to model potential tsunamis from ruptures along the Java Trench based on several different fault parameters, distance, and coastal topography to interpret possible tsunami

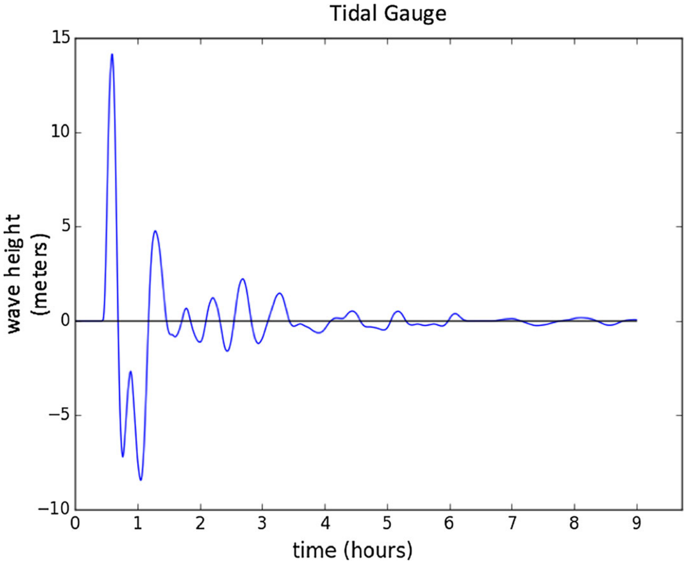

Fig. 3 Output from numerical model of Java megathrust earthquake using GeoClaw tsunami modeling software. Simulated tidal gauge 6 km offshore of Pacitan at a water depth of 15 m. The gauge data predicts wave arrival only 20 min after the earthquake and wave heights in 15 m

arrival times, run-up heights and inundation (Fig. 3). These parameters include the location, orientation, and extent of the earthquake, and the amount and direction of slip of the fault that produced it. Based on the numerical models of likely tsunami events, we created survey questions to determine baseline perceptions of duration of earthquake shaking before evacuation should take place (20 s), length of time to evacuate (20 min), and evacuation height (20 m) or the "20/20/20 principle." Because duration of continuous shaking correlates with length of rupture and actual earthquake magnitude, and not felt intensity of shaking, we developed questions about what is most important in determining whether or not to evacuate (intensity vs. length of shaking). We also developed questions regarding awareness of how long to stay on high ground after a tsunami occurs (at least 3 h based on our modeling after a long-duration—20 s or greater—earthquake to avoid any additional incoming tsunami waves after the first arrivals). We also assessed awareness of natural warning signs, such as the ocean receding.

To assess evacuation intentions, we developed questions such as "when would you evacuate," "what would you do if a tsunami was coming," and "how would you evacuate." To gather additional information and aid in future intervention planning, we assessed history of participation in tsunami evacuation simulations in each area. We also asked what information sources have previously taught them about tsunamis and how they would prefer to be warned in the event of a future tsunami.

2.2 Study participants and site selection

Students at middle (SMP) and high schools (SMA) aged 14–18 ($N = 887$) were surveyed along three tsunami-vulnerable coastal towns in Java, Indonesia: Pelabuhan Ratu ($N = 326$), Pangandaran ($N = 323$), and Pacitan ($N = 238$). Surveys were carried out in collaboration with the National Disaster Mitigation Agency (BPBD). Pencil/paper surveys were distributed during school and individually completed in the classroom.

A total of 372 of the respondents were male (41.9%), 488 were female (55.0%), and 27 did not answer (3.0%). All respondents were between 14 and 18 years of age. In total, 842 of the respondents (94.9%) identified as Muslim, while 30 respondents (3.4%) did not answer. Fewer than 1.0% identified in each of the remaining categories including Buddhist, Catholic, Hindu, Protestant, and Other.

The selected locations were cities along the south coast of Java. Each of the three geographic areas had different backgrounds with the potential to lead to different perceptions of risk, efficacy, and knowledge. Pangandaran had experienced a tsunami that killed more than 600 people in 2006, while Pelabuhan Ratu and Pacitan had not experienced a tsunami in recent memory. Pacitan BPBD had been recognized by the government as a model of preparedness and won several disaster resiliency awards. Pelabuhan Ratu, which has had no recent tsunamis and no strong history of governmental tsunami preparedness interventions, was selected as a control.

2.3 Statistical analysis

The pen/paper surveys were manually entered into Excel. These data were cleaned and uploaded to SPSS. Pearson's Chi-square was used to assess differences in sampling distribution across the three geographic areas, and no significant differences ($p < 0.05$) were found. Scale variables were analyzed using one-way ANOVAs to investigate mean differences in perceptions of threat of natural hazards and tsunami efficacy across geographic locations. Significant results were probed with Tukey's Honest Significant Difference

(HSD) tests. Cross-tabulation was used to determine the number of people in each geographic location, along with the total number of people, for each categorical response for all additional questions.

3 Results

3.1 Perceptions of threat and efficacy

Participants in the three survey locations were asked to rate their level of agreement with the following statements: "it is likely my community will be affected by a flood/earthquake/tsunami" (1 = strongly disagree, 5 = strongly agree). Overall results indicated perceptions of flood risk ($M = 3.75$, $SD = 1.04$) and earthquake risk ($M = 3.86$, $SD = 0.97$), to be lower than perceptions of tsunami risk ($M = 4.00$, $SD = 1.09$) with participants overall agreeing that they are susceptible to tsunami. The mean for the "control" location was lower than those of the other two regions: Pelabuhan Ratu ($M = 3.79$), Pangandaran ($M = 4.03$), and Pacitan ($M = 4.21$). Participants were also asked to rate their level of agreement with the statement "if a tsunami happened, I would be able to save myself". The overall mean for all three locations fell between "neutral" and "agree" ($M = 3.44$, $SD = 1.11$). While Pacitan showed the highest perception of risk, it also showed the lowest perception of efficacy: Pacitan ($M = 3.29$), Pelabuhan Ratu ($M = 3.41$), Pangandaran ($M = 3.54$) (Fig. 4).

3.2 Perceptions of tsunami causes and warning signs

To assess perceptions of possible causes of tsunamis, participants were given the select-all-that-apply question "what could cause a tsunami?" The majority (89.2%) of participants recognized that earthquakes could cause tsunamis, and this was consistently high across locations (86.6–92.9%). The next most common responses were "Will of God" (75.3%), volcanic eruption below sea (73.1%), meteorite/asteroid strike into the ocean (56.4%),

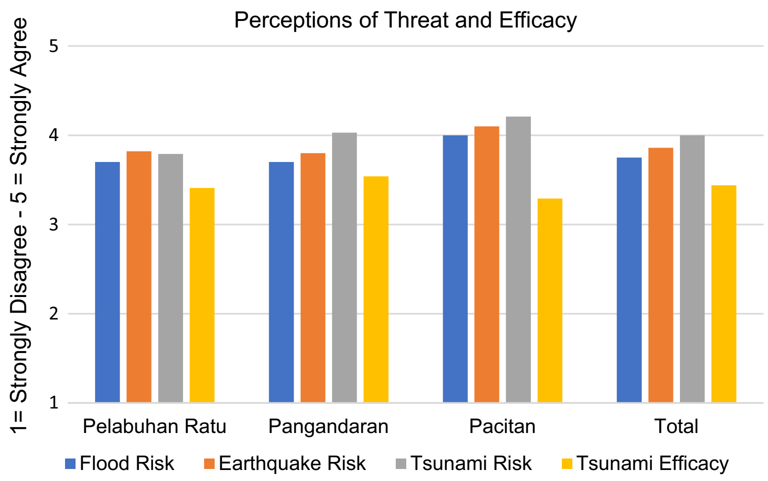

Fig. 4 Perceptions of threat and efficacy

volcanic eruption above sea (50.7%), landslide below sea (32.0%), landslide above sea (14.9%), and other (10.8%). Open-ended responses for "other" included "tectonic plates," "destiny," and "heavy rain." Responses varied across locations, but particularly for perceptions of volcanic eruptions below sea causing tsunamis (Fig. 5).

Awareness of the type of earthquake that can cause a tsunami was assessed with the question "how do you best know if an earthquake is likely to cause a tsunami?" 58.1% of participants responded "*both* how long and how hard the ground shakes," while 26.5% responded "how *hard* the ground shakes", with only 12.1% responding "how *long* the ground shakes". Responses varied across regions; however, length of ground shaking was considered less important across all regions (8.8–14.9%). 2.0% of participants responded that earthquakes do not cause tsunamis, and 1.4% did not respond to the question (Fig. 6).

Knowledge of natural warning signs of tsunamis was assessed using the select-all-that-apply question "which of the following are some of the natural warning signs to evacuate?" (Fig. 7). 73.5% of participants correctly responded that the ocean receding is a natural warning sign to evacuate, and this was fairly consistent across locations (70.6–75.2%). 65.4% of participants responded that the ground shaking very hard was a natural warning sign of an impending tsunami, and this was fairly high across all regions (55.0–77.0%). Fewer responded that various lengths of time shaking were natural warning signs: 10 s (15.8%), 20 s (29.1%), and 1 min (50.2%). Pacitan had a much higher percentage of students reporting ground shaking at least 20 s as a sign to evacuate compared to the other two regions (see limitations section).

3.3 Participation in evacuation simulations

Survey participants were asked whether they had previously participated in a tsunami evacuation simulation. 55.7% of respondents reported that they have never participated in a

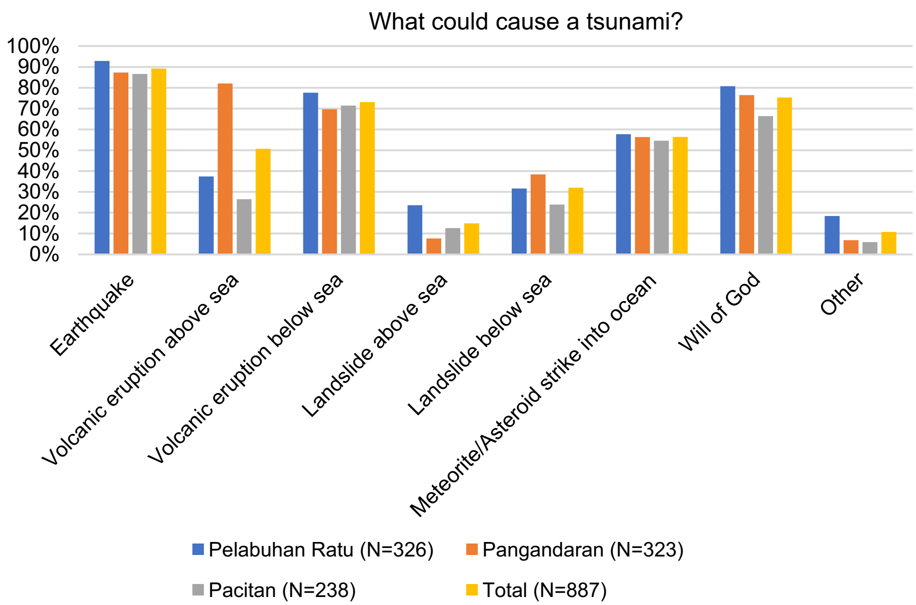

Fig. 5 Perceptions of tsunami cause

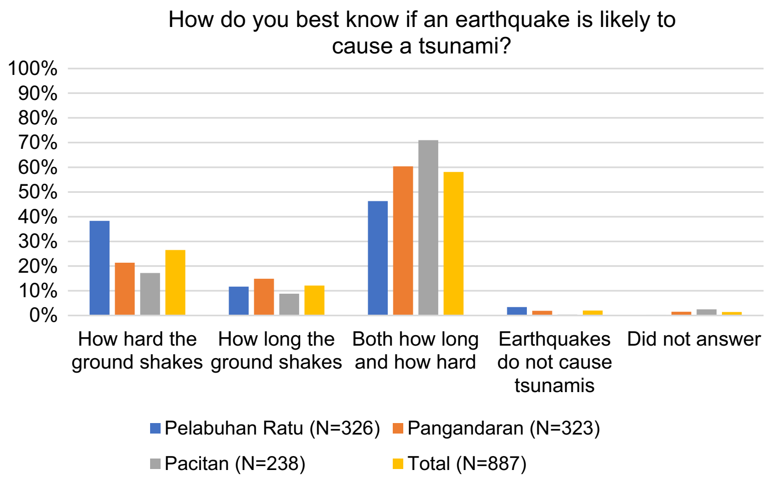

Fig. 6 Perceptions of type of earthquake that can cause a tsunami

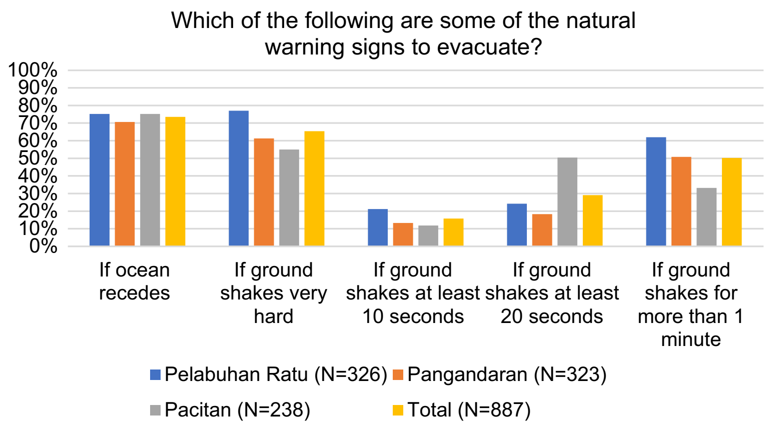

Fig. 7 Awareness of natural tsunami warning signs

tsunami evacuation drill; 41.7% of these reported that they do not have evacuation simulations, while 14.0% said they have had simulations but did not participate. 40.4% of respondents reported that they had participated in an evacuation simulation. 3.9% did not answer. There were large differences between geographic regions. While a much smaller proportion of students in Pelabuhan Ratu and Pacitan reported participating in a previous drill (26.1–28.8%), 62.5% of students in Pangandaran reported previously participating in a simulation (Fig. 8).

3.4 Evacuation perceptions

When asked about what would best protect them from a tsunami, the majority of respondents (84.1%) answered "running to a vertical height of 20 m or more" and this was relatively high across all locations (81.3–86.6%). Very few answered that they would stay

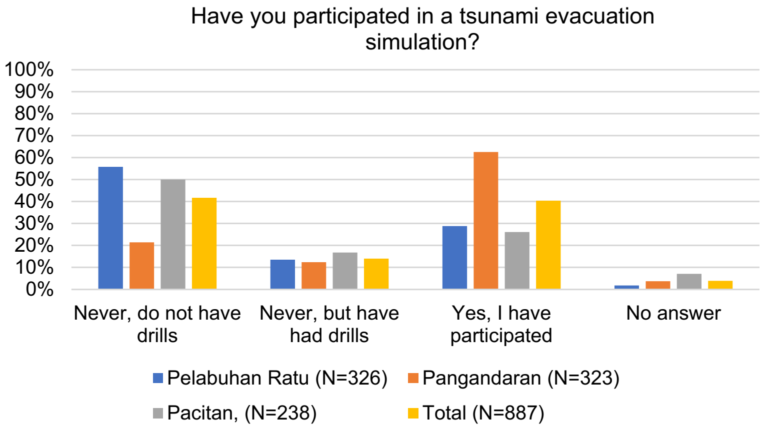

Fig. 8 Participation in previous tsunami evacuation simulations

where they were (0.3%) or that there was nothing they could to do protect themselves (2.6%). However, 9.1% of respondents answered that "running inland 20 m or more" would best protect them from a tsunami (Fig. 9). It should be noted that this question was designed for selection of only one response; however, 3.5% of participants selected multiple responses (the majority of these selected both inland and vertical). These participants ($N = 29$) were dropped from the analysis for this question only.

To assess perceptions of the evacuation window, respondents were asked "about how long would you have to evacuate from the time the earth starts shaking until the time the wave hits?" While 13.9% thought they had only 5 min and 39.6% said they had 20 min, 42.2% of respondents thought they had an hour or more to evacuate (Fig. 10). More than twice the proportion of people located in Pacitan (67.6%) answered 20 min as the amount of time they had to evacuate compared to Pelabuhan Ratu (27.9%) and Pangandaran (30.7%) (see limitations section).

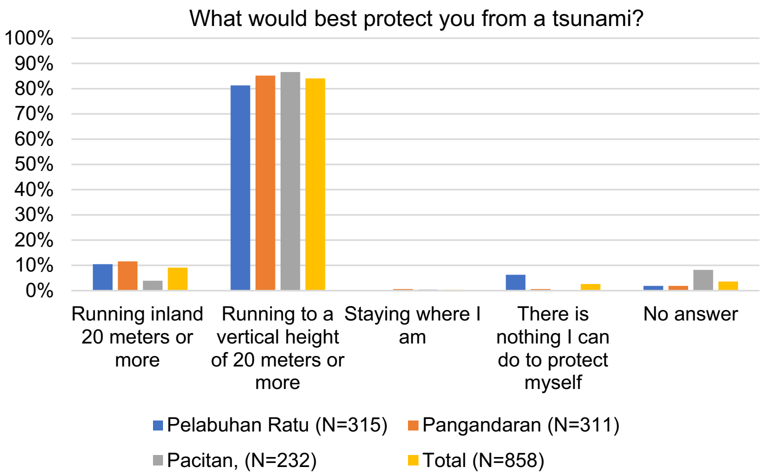

Fig. 9 Perceptions of where to go for evacuation

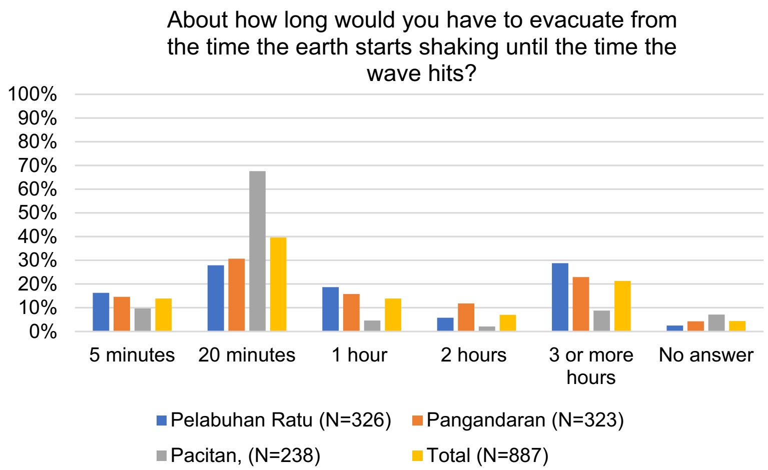

Fig. 10 Evacuation window perceptions

Participants were asked "after a tsunami happens, how long should I wait before I go home?" 69.4% of participants answered correctly with 3 h or more, while 14.3, 8.0, and 3.3% responded 1 h, 20 min, and 5 min, respectively (Fig. 11).

3.5 Evacuation intentions

To assess participant evacuation intentions, we asked "when would you evacuate?" The most common responses were "an alert or order of the authorities to evacuate" (85.0%), "if I saw natural warning signs" (76.4%), "if I saw that other people were evacuating" (43.9%), and "information from family or friend" (37.7%). Few students (2.9%) reported that they would not evacuate (Fig. 12).

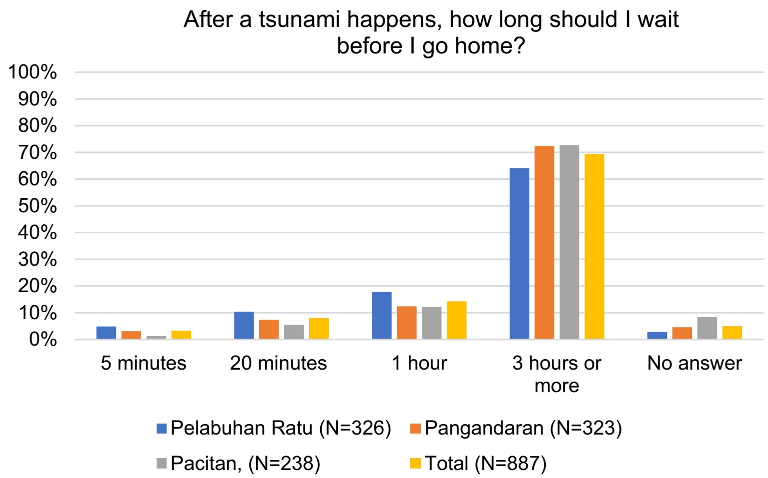

Fig. 11 Perceptions of how long to stay on high ground after a tsunami wave hits

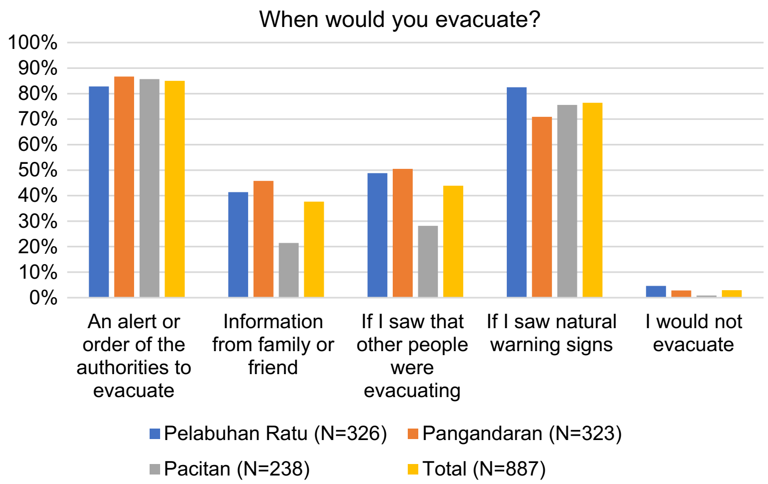

Fig. 12 Participant's intentions of actions to take in the event of a tsunami

To assess more specific evacuation intentions, participants were asked "what would you do if a tsunami was coming?" The majority of respondents (93.5%) responded that they would go up a hill or mountain. The next most common response was evacuating inland (84.9%) and climbing up stairs of a tall building (23.8%). Fewer participants answered go toward the ocean (2.4%), stay inside (1.6%), or other (9.8%) (Fig. 13). "Other" responses, in order of most to least common, were "climb a tree," "evacuate from the shore/ocean," "run," "pray," "helicopter," "get on the roof," "prepare a life vest," and "mosque."

Participants were asked how they would evacuate if a tsunami was coming. The majority of participants reported that they would evacuate by foot (34.5%) or motorcycle (34.5%). Fewer reported that they would evacuate by car (13.6%), that they would not evacuate (6.3%), or other (21.8%) (Fig. 14). The vast majority of "other" responses were

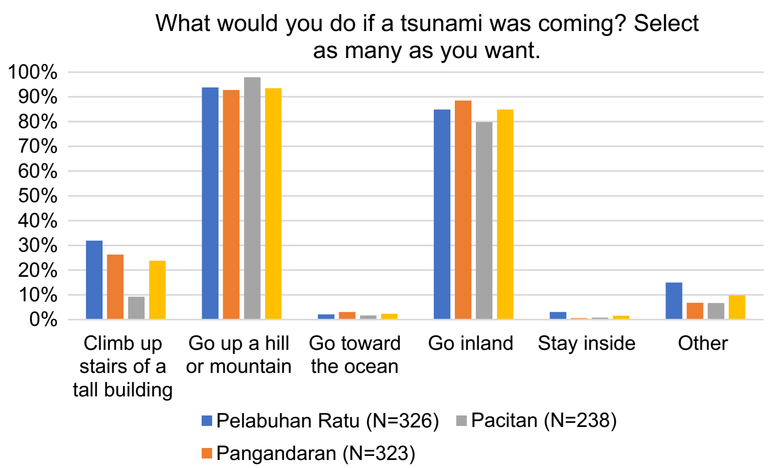

Fig. 13 Participant's reports of under what conditions they would intend to evacuate

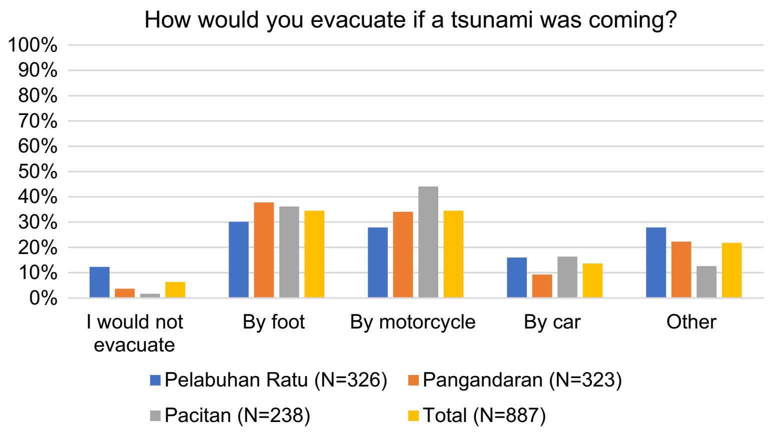

Fig. 14 Intentions to use various evacuation transportation methods in the event of a tsunami

"run," "run quickly," or "evacuate." Additional "other" responses included "any type of transportation," "helicopter," "airplane," and "mosque."

3.6 Communication channels

Students were asked to select sources from which they had learned about tsunamis. Overall, the largest portion of students reported learning about tsunamis in school (71.5%). Over half of the participants reported learning about tsunamis through TV or radio (55.1%) and Internet (52.2%) with the next most popular communication channel being social media (42.7%). More than one-third of participants reported hearing about tsunamis through family (37.4%) and the BPBD (34.3%). The least reported communication channels were friends (15.9%), personal experience (13.2%), neighbors (8.0%), and other (6.0%) (Fig. 15).

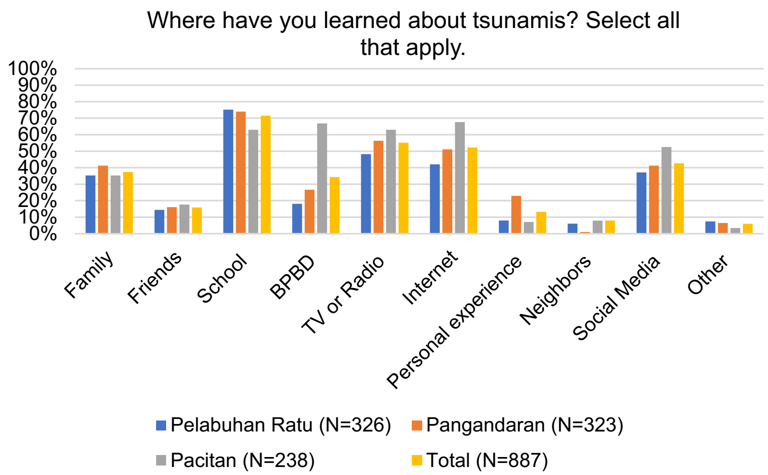

Fig. 15 Sources of tsunami-related information

In line with our site selection criteria, more participants reported learning about tsunamis from personal experience in Pangandaran (22.9%) compared to Pelabuhan Ratu (8.0%) and Pacitan (7.1%). Similarly, more students in Pangandaran reported hearing about tsunamis from their family (41.2% in Pangandaran; 35.3% in the other two locations). Again in line with our selection criteria, more students reported hearing about tsunamis from the BPBD in Pacitan (66.8%) compared to Pelabuhan Ratu (18.1%) and Pangandaran (26.6%). A higher percentage of students in Pacitan also reported TV/radio, Internet, and Social Media as communication sources.

3.7 Warning preferences

Participants were asked "how would you most like to be warned about a tsunami that is coming?" The preferred warning method was through a siren (47.8%). This was followed by TV (22.4%) and self-observing natural warning signs (21.4%). Radio (12.4%), personal cell phone warning (11.5%), local leader (8.9%), and other (4.5%) were lesser preferred methods (Fig. 16). "Other" responses included "government" and "observing ocean."

4 Discussion

4.1 Perceptions of risk and efficacy

The majority of participants reported that they believed they are at risk of a tsunami. Participants in the "control" region (Pelabuhan Ratu) had a lower perceived risk of tsunami than those in Pangandaran and Pacitan. Personal experience with tsunami in Pangandaran and disaster education measures in Pacitan likely heightened perceived risk of tsunami. However, Pacitan participants had the lowest perceived efficacy, despite being the model city of preparedness. Our results are in line with a New Zealand study that showed public education campaigns resulting in a high awareness of risk but low levels of preparedness (Johnston et al. 2013). The authors concluded that risk perception does not

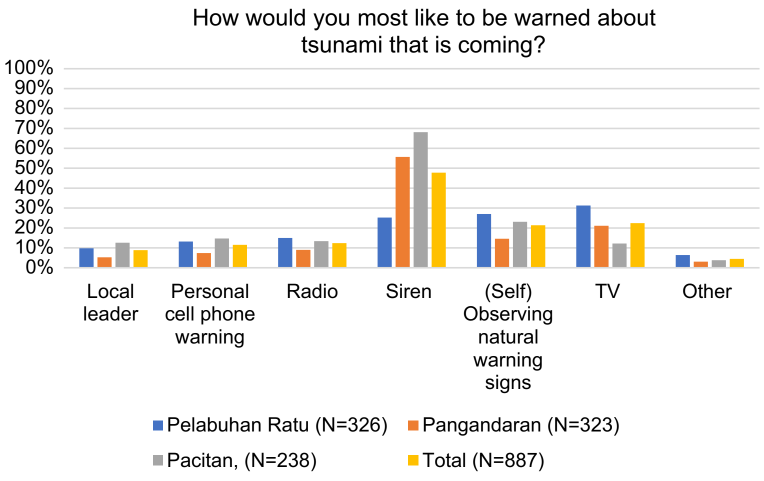

Fig. 16 Preferred tsunami warning method

usually link directly with preparedness. Our results similarly suggest that tsunami awareness interventions should include, at the very least, confidence-building components of self-efficacy and response efficacy. Citizens must not only believe they are at risk of a deadly tsunami, but also that they are able to save themselves and that suggested evacuation protocols will effectively spare them.

4.2 Perceptions of tsunami causes and warning signs

There was a high level of knowledge among participants regarding earthquakes as a source of tsunamis (89.2%) and the ocean receding (73.5%) as a sign of an impending tsunami. "Will of God" was the second most popularly selected answer after earthquakes in response to what could cause a tsunami. Most people surveyed did not view landslides as being able to cause a tsunami (under sea 32.0%, above sea 14.9%). Although volcanoes and landslides could cause localized tsunamis in the region, a further-reaching, regional tsunami is most likely to result from an earthquake, and participants overall were aware of the link.

A key finding with significant implications is that survey participants believed that they must feel intense shaking for an earthquake to cause a tsunami. The most recent earthquakes in Java that generated tsunamis (1994 and 2006) were slow-rupture events (Fujii and Satake 2006), which do not produce intense shaking but do produce larger than expected tsunamis. In some cities with hundreds of fatalities these earthquakes were barely felt. Only 12.1% of our sample believed that the length of shaking was most important in determining if a tsunami may come, and 84.6% believed the ground had to be shaking hard or both long and hard to cause a tsunami. To prevent loss of life, educational interventions should emphasize that earthquakes do not have to feel strong or dramatic to cause a tsunami, and that evacuation should take place if the earth shakes for 20 s or more, regardless of the strength of the shaking.

4.3 Reported evacuation simulation history

The percentage of people who have participated in evacuation simulations differed significantly between regions. In a location where a tsunami had occurred in recent memory (Pangandaran), more people reported participating in simulations (62.5 vs. 26.1 and 28.8%). Over half of participants in Pelabuhan Ratu and Pacitan reported that they do not have simulations. Even though a higher proportion of students in Pangandaran reported participating in simulations, these students were no more aware of other recommended evacuation protocols (such as evacuating within 20 min, that weak earthquakes can cause tsunamis, and staying on high ground for 3 h or more) when compared to the other locations.

These results suggests that although participation in simulations may allow students to know *where* to evacuate, the simulations have not improved knowledge of *under what circumstances* they should evacuate and other vital warnings signs and recommended behaviors. Education is more important than experience with regard to knowledge of tsunami evacuation recommendations. Our findings suggest that there is a need for evacuation simulations; however, it is vital these simulations are combined with education about other tsunami warning signs and evacuation recommendations (e.g., 20/20/20 principle, weak earthquakes can cause tsunamis, stay on high ground for 3 h or more after the first wave hits).

4.4 Evacuation protocol perceptions

An encouraging finding was that when participants were asked what would best protect them from a tsunami, the vast majority chose vertical evacuation over running inland or other options. This result indicates a high level of knowledge of where to go to evacuate among our study participants. However, although the majority of students were aware they need to evacuate to high ground, one key finding with significant implications is that almost 42.2% of participants believed they would have an hour or more to evacuate; more than 20% believed they would have 3 h or more to evacuate.

Our reported pre-intervention knowledge levels of the suggested evacuation window (20 min) were inflated in Pacitan because our 20/20/20 intervention travelled ahead of us through word-of-mouth. Results for baseline knowledge of the suggested 20-min evacuation window in Pacitan are likely much too high. A truer reflection of baseline knowledge is likely closer to the baseline knowledge level of respondents from our first two sites. In these two locations, 53.3% (Pelabuhan Ratu) and 50.5% (Pangandaran) thought they had an hour or more to evacuate. Teaching the 20/20/20 principle is needed as an educational intervention to alert people that they have less time to evacuate than they think in order to best protect themselves from a tsunami. Our confounded baseline data in Pacitan suggests that the 20/20/20 intervention does indeed improve knowledge about the suggested tsunami evacuation windows.

Although nearly 70% of participants stated that they should wait for 3 h or more before returning home after a tsunami wave, there is still room to improve the 30% who did not respond that they should wait for 3 h or more. Geoscientists should work with the local BPBD organizations and communities to establish evacuation protocols based on geologic modeling, and disaster mitigation specialists should work with locals to effectively disseminate these protocols to the general public.

4.5 Evacuation intentions

Most individuals (85.0%) surveyed responded that they would evacuate due to an order/alert from the authorities, while fewer reported that they would evacuate if they observed natural warning signs (76.4%). Although a relatively high percentage reported they would evacuate based on natural warning signs, our data indicate that natural warning signs are not well understood. While the majority (73.5%) of participants indicated that they believed a receding ocean indicated an approaching tsunami, if these individuals are not near the ocean prior to the tsunami event, or the tsunami happens at night, they are unlikely to observe the warning sign. Furthermore, respondents overall believed there had to be strong or dramatic shaking for an earthquake to cause a tsunami. Experiencing a long but weak earthquake is unlikely to prompt self-evacuation. Increased communication and education are required to provide increased knowledge of natural warning signs to community members and encourage self-evacuation.

While the majority of people knew that they should go uphill if a tsunami was coming, about 85% also believed that going inland would help them, which may not be the case if they do not gain vertical ground as well. However, the majority of respondents chose vertical over inland when asked what would best protect them (84.1%) over inland (9.1%). Vertical evacuation in buildings was not generally viewed as an option and varied widely by region (e.g., 9.2% in Pacitan vs. 31.9% Pelabuhan Ratu). Educational interventions should stress that vertical evacuation is more important than going inland or simply away from the shore. More research is needed on perceptions and knowledge of vertical evacuation shelters.

Evacuation by foot or motorcycle was the most common evacuation intention. Although this is often encouraged in order to avoid unnecessary deaths due to traffic jams, it should be noted that our sample consisted of junior high and high school students who may not drive or own a car. More research is required to address what transportation methods adults in Java intend to use for tsunami evacuation.

4.6 Communication channels

"School" (71.5%) was reported as the most common communication channel from which students have learned about tsunamis, suggesting that tsunami education for youth is a priority on the island of Java. These data may indicate that older adults (especially those who attended school prior to 2004) may not be as educated about tsunamis as the youth. However, TV and radio, which are generally more available to a broader demographic, were also reported as common channels (55.1%). The Internet (52.2%) and Social Media (42.7%) were also frequently reported as sources of information. Indonesia is "one of the highest users of mobile technology and social networking" (Beger et al. 2012, p. 4). In regard to technology and social media use, adolescents and youth are the two top groups of consumers (Beger et al. 2012). For those on the island of Java, TV and radio, Internet, and social media alerts have the potential to effectively reach this population.

Word-of-mouth channels such as family (37.4%), friends (15.9%), and neighbors (8.0%), were less commonly reported. Students in Pangandaran were approximately three times as likely to report personal experience as a source of knowledge; however, since these individuals did not perform better on critical awareness questions, this suggests that education is more important than experience with regard to disaster mitigation.

The most notable difference in communication channels between cities was the percentage of students that reported learning about tsunamis through the government disaster mitigation agency (BPBD) (66.8% in Pacitan, 26.6% in Pangandaran, and 18.1% in Pelabuhan Ratu). Pacitan BPBD was a large factor in our 20/20/20 intervention travelling ahead of us by word-of-mouth, which was reflected by significantly increased student knowledge of evacuation window times. This evidence suggests that local political will is an important factor in improving critical awareness of tsunamis and evacuation protocols.

Pacitan also showed a higher percentage of students who reported learning about tsunamis through channels such as TV or radio, Internet, and social media. In contrast, students in Pelabuhan Ratu were less likely to report hearing about tsunamis from social media, Internet, TV or radio, compared to the other study sites. These data suggest regional differences in exposure to tsunami-related information. Interventions should take advantage of communication channels such as TV, radio, Internet, and social media to increase tsunami preparedness communication. In addition, it may be advantageous to identify and work with schools and local BPBD organizations that show a commitment to tsunami education.

4.7 Warning preferences

The majority of participants responded that they would prefer to be warned of an impending tsunami through a siren (47.8%). In contrast, fewer than half as many (21.4%) selected "self-observing natural warning signs." This is problematic considering the lack of reliability that sirens have had in this area in the past. Issues such as sirens sounding too late, ending too early, or not sounding at all during a tsunami have and could result in further loss of life if local communities rely on these federal government initiatives to initiate evacuation. Outside interventions aimed at shifting local tsunami warning preferences away from federal warning and toward self-observation may prove difficult considering cultural clashes between "Western" individualistic cultures and the culturally hierarchical Java (Irawanto 2011). Only 8.9% of survey respondents selected "local leaders" as a warning preference, and our informal interviews with local leaders found that they do not want the responsibility or accountability of warning their communities. One concern of local leaders was that if they urge community evacuation based on natural warning signs and a tsunami does not come, they will "lose trust" of individuals within their community. It is unlikely that a widespread initiative training local community leaders will significantly improve tsunami evacuation. However, interventions working with local preparedness initiatives and committed local BPBD organizations may be useful.

5 Conclusions and recommendations

Our surveys indicate that adolescents on tsunami-vulnerable coastal areas of Java already believe there is a high risk of tsunami, but perceptions of efficacy with regard to tsunami evacuation could be improved. Overall, students who associate tsunamis with earthquakes and tectonic plates know that a receding ocean is a sign of an impending tsunami, and believe vertical evacuation is more important than inland evacuation.

However, several knowledge gaps exist, such as misconceptions regarding the type of earthquake that can cause a tsunami (e.g., the belief that shaking has to feel strong or dramatic), that the time of shaking is relatively unimportant, believing that they have more time to evacuate than the suggested evacuation window (20 min), and not knowing they should remain on high ground for 3 h or more after a wave hits. Additionally, the preference for being warned by sirens rather than observing natural warning signs is a challenging issue that must be addressed by working alongside locals and in culturally sensitive ways.

Our data showed regional differences in evacuation simulation history, personal experience with tsunamis, and the local BPBD as a source of tsunami education information. However, neither participation in evacuation simulations nor personal experience with tsunamis translated to increased knowledge of when or how to evacuate. We argue that education is more important than experience with regard to tsunami readiness. There is opportunity to more effectively disseminate information addressing tsunami preparedness through TV, radio, Internet, and Social Media.

We conclude that evacuation simulations, coupled with education on the 20/20/20 principle, be implemented throughout Java in partnership with local disaster mitigation agencies. In addition, short messages stressing that even weak earthquakes can cause tsunamis should be communicated through a variety of channels, as this is a misunderstood but critically important component of information with regard to self-evacuation. Interventions should take care when using educational material showing dramatic or strong earthquakes when discussing the relationship between earthquakes and tsunamis, as community members may interpret this as a prerequisite for a tsunami, which could lead to decreased intentions to evacuate if the earthquake is not strong. In addition, education measures should provide awareness of how a tsunami might look as it approaches shore in order to correct misconceptions.

6 Limitations

There are several limitations to our preparedness assessment. First, the assessment was conducted among youth aged 14–18 and should not be more broadly applied to the general population of Java. Since school was the most frequently reported source for tsunami-related information among our study population, it is likely that the general adult population is less knowledgeable than this sample suggests. Further assessment is required at the community level for intervention programs aimed at the general population. Furthermore, our study population may have been too young to fully realize the devastation of the 2004 Indian Ocean tsunami or 2006 Pangandaran tsunami. However, our data is useful for planning tsunami preparedness interventions among at-risk adolescents in Java. Additionally, this assessment reveals knowledge gaps about preparedness that do not appear to be taught in school or received from other communication channels that can be used to plan future community-level interventions.

Some questions in our study were confounded because our 20/20/20 intervention following our assessments in each city travelled ahead of us via word-of-mouth. Although data from Pelabuhan Ratu and Pangandaran accurately reflect baseline knowledge, the Pacitan data are confounded in some instances due to word-of-mouth education through local government organizations, school headmasters, and community leaders. Several results showed heightened knowledge of the 20/20/20 principle in Pacitan compared to the other locations. For example, a much higher percentage of students in Pacitan (67.6%) answered "20 min" as the amount of time they had to evacuate compared to Pelabuhan Ratu (27.9%) and Pangandaran (30.7%). Judging by the relative consistency between the other two locations, it is likely that overall baseline data perceptions of length of time to evacuate are lower than that suggested by our combined percentage of all three locations and closer to the percentages suggested by Pelabuhan Ratu and Pangandaran. This suggests that there is even more need for intervention than our overall results demonstrate. Although this is a data limitation, it is encouraging that the 20/20/20 principle spread via word-of-mouth so quickly and improved knowledge of several tsunami evacuation principles so drastically.

Finally, while educational efforts are invaluable in disaster mitigation, education alone is not the only solution. Evacuation behaviors are determined not only by knowledge levels, but also by response capability influenced by geography and infrastructure, population demographics, and policy and planning. Geography and infrastructure, such as land cover, slope, population density, access to transportation networks, evacuation bottlenecks, and density of critical facilities (e.g., primary schools, hospitals), influence response capability (Løvholt et al. 2014; Post et al. 2009). Particularly, vulnerable groups include women, children, the elderly, low-income groups, individuals with disabilities and special needs, and people living near the coast (Løvholt et al. 2014; Sullivan and Häkkinen 2006). Policy and planning influence tsunami resilience through preparedness, relief, and recovery planning (e.g., community preparedness plan, risk maps, medical help planning). Other policy efforts such as flood defenses, land use planning, decreasing settlements close to the sea, and creating building and home standards are important (Esteban et al. 2013). A holistic approach to tsunami disaster mitigation efforts should include working with local organizations to address these factors, in addition to providing educational assessments, interventions, and evaluation.

Acknowledgement Funding was provided by Utah Valley University (Grant No. GEL Grant 629).

Appendix

See Table 1.

Table 1 Survey Results

Survey results (N) (%)	Pel. Ratu (N = 326)	Pangandaran (N = 323)	Pacitan (N = 238)	Total (N = 887)
What could cause a tsunami?				
Earthquake	303: 92.9%	282: 87.3%	206: 86.6%	791: 89.2%
Volcanic eruption above sea	122: 37.4%	265: 82.0%	63: 26.5%	450: 50.7%
Volcanic eruption below sea	253: 77.6%	225: 69.7%	170: 71.4%	648: 73.1%
Landslide above sea	77: 23.6%	25: 7.7%	30:12.6%	132: 14.9%
Landslide below sea	103: 31.6%	124: 38.4%	57: 23.9%	284: 32.0%
Meteorite/Asteroid strike into ocean	188: 57.7%	182: 56.3%	130: 54.6%	500: 56.4%
Will of God	263: 80.7%	247: 76.5%	158: 66.4%	668: 75.3%
Other	60: 18.4%	22: 6.8%	14: 5.9%	96: 10.8%
How do you best know if an earthquake is likely to cause a tsunami?				
How hard the ground shakes	125: 38.3%	69: 21.4%	41: 17.2%	235: 26.5%
How long the ground shakes	38: 11.7%	48: 14.9%	21: 8.8%	107: 12.1%
Both how long and how hard	151: 46.3%	195: 60.4%	169: 71.0%	515: 58.1%
Earthquakes do not cause tsunamis	11: 3.4%	6: 1.9%	1: 0.4%	18: 2.0%
Did not answer	1: 0.3%	5: 1.5%	6: 2.5%	12: 1.4%
Which of the following are some of the natural warning signs to evacuate?				
If ocean recedes	245: 75.2%	228: 70.6%	179: 75.2%	652: 73.5%
If ground shakes very hard	251: 77.0%	198: 61.3%	131: 55.0%	580: 65.4%
If ground shakes at least 10 s	69: 21.2%	43:13.3%	28: 11.8%	140: 15.8%
If ground shakes at least 20 s	79: 24.2%	59: 18.3%	120: 50.4%	258: 29.1%
If ground shakes for more than 1 min	202: 62.0%	164: 50.8%	79: 33.2%	445: 50.2%
Have you participated in a tsunami evacuation simulation?				
Never, do not have drills	182: 55.8%	69: 21.4%	119: 50.0%	370: 41.7%
Never, but have had drills	44: 13.5%	40: 12.4%	40: 16.8%	124: 14.0%
Yes, I have participated	94: 28.8%	202: 62.5%	62: 26.1%	358: 40.4%
No answer	6: 1.8%	12: 3.7%	17: 7.1%	35: 3.9%
What would best protect you from a tsunami?[a]				
Running inland 20 m or more	33: 10.5%	36: 11.6%	9: 3.9%	78: 9.1%
Running to a vertical height of 20 m…	256: 81.3%	265: 85.2%	201: 86.6%	722: 84.1%

Table 1 continued

Survey results (*N*) (%)	Pel. Ratu ($N = 326$)	Pangandaran ($N = 323$)	Pacitan ($N = 238$)	Total ($N = 887$)
Staying where I am	0: 0%	2: 0.6%	1: 0.4%	3: 0.3%
There is nothing I can do to protect…	20: 6.3%	2: 0.6%	0: 0%	22: 2.6%
No answer	6: 1.9%	6: 1.9%	19: 8.2%	31: 3.6%
About how long would you have to evacuate from the time the earth starts shaking until the time the wave hits?[b]				
5 min	53: 16.3%	47: 14.6%	23: 9.7%	123: 13.9%
20 min	91: 27.9%	99: 30.7%	161: 67.6%	351: 39.6%
1 h	61: 18.7%	51: 15.8%	11: 4.6%	123: 13.9%
2 h	19: 5.8%	38: 11.8%	5: 2.1%	62: 7.0%
3 or more hours	94: 28.8%	74: 22.9%	21: 8.8%	189: 21.3%
No answer	8: 2.5%	14: 4.3%	17: 7.1%	39: 4.4%
After a tsunami happens, how long should you wait before you go home?				
5 min	16: 4.9%	10: 3.1%	3: 1.3%	29: 3.3%
20 min	34: 10.4%	24: 7.4%	13: 5.5%	71: 8.0%
1 h	58: 17.8%	40: 12.4%	29: 12.2%	127: 14.3%
3 h or more	209: 64.1%	234: 72.4%	173: 72.7%	616: 69.4%
No answer	9: 2.8%	15: 4.6%	20: 8.4%	44: 5.0%
When would you evacuate? Select all that apply				
An alert or order of the authorities…	270: 82.8%	280: 86.7%	204: 85.7%	754: 85.0%
Information from family or friend	135: 41.4%	148: 45.8%	51: 21.4%	334: 37.7%
If I saw that other people were evacuating	159: 48.8%	163: 50.5%	67: 28.2%	389: 43.9%
If I saw natural warning signs	269: 82.5%	229: 70.9%	180: 75.6%	678: 76.4%
I would not evacuate	15: 4.6%	9: 2.8%	2: 0.8%	26: 2.9%
What would you do if a tsunami was coming? Select all that apply				
Climb up stairs of a tall building	104: 31.9%	85: 26.3%	22: 9.2%	211: 23.8%
Go up a hill or mountain	306: 93.9%	300: 92.9%	223: 93.7%	829: 93.5%
Go toward the ocean	7: 2.1%	10: 3.1%	4: 1.7%	21: 2.4%
Go inland	277: 85.0%	286: 88.5%	190: 79.8%	753: 84.9%
Stay inside	10: 3.1%	2: 0.6%	2: 0.8%	14: 1.6%
Other	49: 15.0%	22: 6.8%	16: 6.7%	87: 9.8%
How would you evacuate if a tsunami was coming?				
I would not evacuate	40: 12.3%	12: 3.7%	4: 1.7%	56: 6.3%
By foot	98: 30.1%	122: 37.8%	86: 36.1%	306: 34.5%
By motorcycle	91: 27.9%	110: 34.1%	105: 44.1%	306: 34.5%
By car	52: 16.0%	30: 9.3%	39: 16.4%	121: 13.6%
Other	91: 27.9%	72: 22.3%	30:12.6%	193: 21.8%
Where have you learned about tsunamis? Select all that apply				
Family	115: 35.3%	133: 41.2%	84: 35.3%	332: 37.4%
Friends	47: 14.4%	52: 16.1%	42: 17.6%	141: 15.9%

Table 1 continued

Survey results (*N*) (%)	Pel. Ratu ($N = 326$)	Pangandaran ($N = 323$)	Pacitan ($N = 238$)	Total ($N = 887$)
School	245: 75.2%	239: 74.0%	150: 63.0%	634: 71.5%
BPBD	59: 18.1%	86: 26.6%	159: 66.8%	304: 34.3%
TV or Radio	157: 48.2%	182: 56.3%	150: 63.0%	489: 55.1%
Internet	137: 42.0%	165: 51.1%	161: 67.6%	463: 52.2%
Personal experience	26: 8.0%	74: 22.9%	17: 7.1%	117: 13.2%
Neighbors	20: 6.1%	32: 1.0%	19: 7.9%	71: 8.0%
Social Media	121: 37.1%	133: 41.2%	125: 52.5%	379: 42.7%
Other	24: 7.4%	21: 6.5%	8: 3.4%	53: 6.0%
How would you most like to be warned about tsunami that is coming?				
Local leader	32: 9.8%	17: 5.3%	30: 12.6%	79: 8.9%
Personal cell phone warning	43: 13.2%	24: 7.4%	35: 14.7%	102: 11.5%
Radio	49: 15.0%	29: 9.0%	32: 13.4%	110: 12.4%
Siren	82: 25.2%	180: 55.7%	162: 68.1%	424: 47.8%
(Self) Observing natural warning signs	88: 27.0%	47: 14.6%	55: 23.1%	190: 21.4%
TV	102: 31.3%	68: 21.1%	29: 12.2%	199: 22.4%
Other	21: 6.4%	10: 3.1%	9: 3.8%	40: 4.5%

[a] Twenty-nine participants who selected more than one response were dropped from this question (Pelabuhan Ratu $N = 11$, Pangandaran $N = 12$, Pacitan $N = 6$). Total $N = 856$ for this question

[b] Pacitan numbers are likely inflated due to our 20/20/20 intervention travelling ahead of us. Baseline knowledge levels are better reflected in the Pelabuhan Ratu and Pangandaran data

References

Badan Meteorologi Klimatologi dan Geofisika (2010) Laporan Gempabumi Mentawai, 25 Oktober 2010, p 18

Beger G, Priscillia KH, Akshay S (2012) Indonesian youth online—an exploratory study of the Indonesian digital landscape. UNICEF New York, Division of Communication, Social and Civic Media Section

Cox D (2001) The inappropriate tsunami icon. Sci Tsunami Hazards

Dash N, Gladwin H (2007) Evacuation decision making and behavioral responses: individual and household. Nat Hazards Rev 8(3):69–77. doi:10.1061/(asce)1527-6988

Edberg M (2013) Essentials of health behavior. Jones & Bartlett Publishers

Esteban M, Tsimopoulou V, Mikami T, Yun NY, Suppasri A, Shibayama T (2013) Recent tsunamis events and preparedness: development of tsunami awareness in Indonesia, Chile and Japan. Int J Disaster Risk Reduct 5:84–97

Fujii Y, Satake K (2006) Source of the July 2006 west Java tsunami estimated from tide gauge records. Geophys Res Lett. doi:10.1029/2006GL028049

Harris RA (2016) Not that kind of doctor: a story of natural disaster prevention in Indonesia. As Environ Eng Geol (AEG) 59(2):30–36

Harris R, Major J (2016) Waves of destruction in the East Indies: the Wichmann catalogue of earthquakes and tsunami in the Indonesian region from 1538 to 1877. In: Cummins PR, Meilano I (eds) Geohazards in Indonesia: earth science for disaster risk reduction. Geological Society, London, Special Publications, pp 441. doi:10.1144/SP441.2

Harris RA, Prasetyadi C (2002) Who's next? Assessing vulnerability to geophysical hazards in densely populated regions of Indonesia. Bridges 2:14–17. doi:10.1144/SP441.2

Irawanto DW (2011) An analysis of national culture and leadership practices in Indonesia. J Divers Manag (JDM) 4(2):41–48

Johnston D, Paton D, Crawford GL, Ronan K, Houghton B, Bürgelt P (2005) Measuring tsunami preparedness in coastal Washington, United States. Nat Hazards 35:173–184. doi:10.1007/1-4020-3607-8_12

Johnston D, Becker J, McClure J, Paton D, McBride S, Wright K, Leonard G, Hughes M (2013) Community understanding of, and preparedness for, earthquake and tsunami risk in Wellington, New Zealand. In: Joffe H, Rosetto T, Adams J (eds) Cities at risk: living with perils in the 21st century. Springer, Netherlands, pp 131–148

Lauterjung J, Münch U, Rudloff A (2010) The challenge of installing a tsunami early warning system in the vicinity of the Sunda Arc, Indonesia. Nat Hazards Earth Syst Sci 10:641–646. doi:10.5194/nhess-10-641-2010

Lay T, Kanamori H, Ammon C, Nettles M, Ward S, Aster R, Beck S, Bilek S, Brudzinski M, Butler R, Deshon H, Ekstrom G, Satake K, Sipkin S (2005) The great Sumatra-Andaman earthquake of 26 December 2004. Science 308:1127–1133

LeVeque RJ, Berger MJ et al (2013) Clawpack software 4.6.3. www.clawpack.org. Mar 26, 2013

Løvholt F, Setiadi NJ, Birkmann J, Harbitz CB, Bach C, Fernando N, Kaiser G, Nadim F (2014) Tsunami risk reduction—Are we better prepared today than in 2004? Int J Disaster Risk Sci 10(A):127–142

Mimura N, Yasuhara K, Kawagoe S et al (2011) Damage from the great East Japan earthquake and tsunami—a quick report. Mitig Adapt Strateg Glob Change 16:803–818. doi:10.1007/s11027-011-9297-7

Newcomb KR, McCann WR (1987) Seismic history and seismotectonics of the Sunda Arc. J Geophys Res 92(B1):421–439. doi:10.1029/JB092iB01p00421

Ortiz M, Bilham R (2003) Source area and rupture parameters of the 31 December 1881 Mw = 7.9 Car Nicobar earthquake estimated from tsunamis recorded in the Bay of Bengal. J Geophys Res. doi:10.1029/2002JB001941

Pararas-Carayannis G (2003) Near and far-field effects of tsunamis generated by the paroxysmal eruptions, explosions, caldera collapses and massive slope failures of the Krakatau volcano in Indonesia on August 26–27, 1883. Sci Tsunami Hazards 21:191–211

Paton D (2003) Disaster preparedness: a social-cognitive perspective. Disaster Prev Manag Int J 12(3):210–216. doi:10.1108/09653563310489686

Post J, Wegscheider S, Mück M, Zosseder K, Kiefl R, Steinmetz T, Strunz G (2009) Assessment of human immediate response capability related to tsunami threats in Indonesia at a sub-national scale. Nat Hazards Earth Syst Sci 9(4):1075–1086

Sorooshian S (2005) Meeting the challenges of natural hazards in the wake of the tsunami disaster. EOS Trans AGU 86(2):14. doi:10.1029/2005EO020005

Spahn H, Hoppe M, Vidiarina HD, Usdianto B (2010) Experience from three years of local capacity development for tsunami early warning in Indonesia: challenges, lessons and the way ahead. Nat Hazards Earth Syst Sci 10(7):1411–1429. doi:10.5194/nhess-10-1411-2010

Strunz G, Post J, Zosseder K, Wegscheider S, Mück M, Riedlinger T, Mehl H, Dech S, Birkmann J, Gebert N, Harjono H, Anwar HZ, Sumaryono G, Khomarudin RM, Muhari A (2011) Tsunami risk assessment in Indonesia. Nat Hazards Earth Syst Sci 11:67–82

Sullivan HT, Häkkinen MT (2006) Disaster preparedness for vulnerable populations: determining effective strategies for communicating risk, warning, and response. In: Third annual Magrann research conference at Rutgers University, vol 4, pp 21-04

Suppasri A, Goto K, Muhari A, Ranasinghe P, Riyaz M, Affan M et al (2015) A decade after the 2004 Indian Ocean tsunami: the progress in disaster preparedness and future challenges in Indonesia, Sri Lanka, Thailand and the Maldives. Pure appl Geophys 172(12):3313–3341. doi:10.1007/s00024-015-1134-6

Wichmann CEA (1918) Die Erdbeben des Indishen Archipels Bis Zum Johpe 1857, (in Dutch), Koninkl. Nederlandse Akad. Wetensch. Verh. 2nd Sect. 20, p 193

Wichmann CEA (1922) Die Erdbeben des Indischen Archipels von 1858 bis 1877, (in Dutch) Amsterdam: Konink. Nederlandse Akad. Wetensch. Verh. 2nd Sect. 22, p 209