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Article

Cascadia Subduction Zone Residents' Tsunami Evacuation Expectations

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Abstract: The U.S. Pacific Northwest coast must be prepared to evacuate immediately after a Cascadia Subduction Zone earthquake. This requires coastal residents to understand the tsunami threat, have accurate expectations about warning sources, engage in preimpact evacuation preparedness actions, and plan (and practice) their evacuation logistics, including an appropriate transportation mode, evacuation route, and destination. A survey of 221 residents in three communities identified areas in which many coastal residents have reached adequate levels of preparedness. Moreover, residents who are not adequately prepared are willing to improve their performance in most of the areas in which they fall short. However, many respondents expect to engage in time-consuming evacuation preparations before evacuating. Additionally, their estimates of evacuation travel time might be inaccurate because only 28–52% had practiced their evacuation routes. These results indicate that more coastal residents should prepare *grab-and-go* kits to speed their departure, as well as practice evacuation preparation and evacuation travel to test the accuracy of these evacuation time estimates. Overall, these results, together with recommendations for overcoming them, can guide CSZ emergency managers in methods of improving hazard awareness and education programs. In addition, these data can guide transportation engineers' evacuation analyses and evacuation plans.

Keywords: tsunami; Cascadia Subduction Zone; evacuation preparedness; evacuation time estimates

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1. Introduction

The US Pacific Northwest coast is vulnerable to tsunamis from many sources around the Pacific Ocean but local tsunamis from the Cascadia Subduction Zone (CSZ) are especially dangerous because of their rapid onset [1]. Consequently, CSZ residents should be aware of tsunamis and their potential impacts. In particular, people who live and work in tsunami zones should be prepared to evacuate immediately after earthquake shaking, whereas residents of nearby areas should be prepared to survive without assistance for an extended period of time [2]. One framework for assessing coastal residents' hazard knowledge and emergency preparedness is the Protective Action Decision Model (PADM) [3–6]. According to the PADM, protective action decisions begin with environmental cues, social cues, and social warnings. When a hazard is imminent, environmental cues provide sights and sounds (e.g., earthquake shaking or sea-level recession) that signal hazard arrival, whereas social cues are observations of others' behavior such as neighbors evacuating. However, longer forewarning of tsunami impact can be produced by warning messages transmitted from sources (e.g., emergency managers, TV weather forecasters, or peers) via channels (e.g., TV, radio, siren, or telephone) to receivers who vary in personal characteristics such as hazard experience, language proficiency, and physical mobility. Warning messages should describe the hazard, especially its expected time of impact, and a protective action recommendation [7].

In addition to understanding factors influencing protective actions, it is also important to understand the temporal characteristic of protective action. Specifically, ref. [8] adopted the definition of the time required for a household to complete an evacuation as a function of four evacuation time estimate (ETE) components; see also [9–11]. Specifically,

$$t_T = f\ (t_d, t_w, t_p, t_e), \tag{1}$$

where t_T is a household's total clearance time, t_d is the authorities' decision time, t_w is the household's warning receipt time, t_p is the household's evacuation preparation time, and t_e is the household's evacuation travel time. Authorities' decision time (t_d) is the interval between authorities' detection of the threat and their decision to warn the risk area population. Warning receipt time (t_w) is highly variable because it depends on the nature of the local warning mechanisms that differ in many ways, with those having the lowest sender and receiver requirements (e.g., emergency responders going door to door) having the slowest rate of dissemination [4,8,12]. Household preparation time (t_p) is also highly variable because it depends on people's expectations about how soon a disaster will strike. During that time, households engage in "milling", which involves confirming the warning and relaying the warning to others [7], as well as preparing to implement protective actions such as evacuation. Finally, evacuation travel (t_e) time depends on the distance people must travel to reach a safe location and the speed at which they can travel. Unfortunately, evacuation routes can become congested during emergencies, so travel speed can be much lower than normal [8].

Distant tsunamis take so long to reach the CSZ that coastal residents can receive social warnings hours before the first wave arrives. The National Tsunami Warning Center (NTWC) will detect the tsunami and notify state emergency management agencies, local emergency management agencies, broadcast news media, and even households that subscribe to NTWC alerts. Households that do not receive NTWC alerts directly can be warned by sirens, National Oceanic and Atmospheric Administration (NOAA) Weather Radio, route alert (e.g., police or fire vehicles broadcasting warnings through loudspeakers), or commercial TV and radio [12]. Households that do not receive official broadcast warnings might receive warnings that are disseminated through the informal peer warning networks or might see peers evacuating. The final warning sources are environmental cues—sea-level drawdown and (ultimately) the sight and sound of a tsunami wave.

Local CSZ tsunamis have such a rapid onset, as little as 15 min, that the principal social warning sources will be unable to transmit warning messages to everyone in time. Thus, environmental and social cues will be the primary warning sources. In particular, earthquake shaking can warn coastal residents of tsunami onset if they understand the connection between the two events. However, when people are warned about a tsunami threat, warning confirmation and evacuation preparation, including choosing an evacuation route and destination, will delay their departure. Moreover, the decision to take a car rather than evacuate on foot can cause traffic jams inside the tsunami zone. Thus, erroneous beliefs about tsunami warning sources and inappropriate evacuation logistics are threats to coastal residents' survival for local tsunamis. Consequently, the next section reviews what is known about coastal residents' beliefs about tsunami warning sources, the sources of these beliefs, and what actions they take (or expect to take) when a tsunami threatens, as well as the length of time people expect those actions to take. Such information can provide vital inputs for tsunami evacuation transportation models and, in turn, community evacuation plans. Information about coastal residents' evacuation expectations can also identify topics for local emergency managers to address in hazard education programs.

1.1. Hazard Experience

Tsunami experience is important because many studies find that it affects risk perception [13] and emergency preparedness [14]. For example, ref. [15] showed that respondents who themselves or whose relatives had experienced a tsunami were three times more likely to evacuate earlier and faster than those without such experience. Moreover, [16] cite a study in which 72% of residents expected earthquake shaking to be followed by a tsunami because of their personal experience with a previous earthquake and tsunami [17], whereas another 15% had learned about the connection from others in the community. However, they also cite an incident in which 35% of residents failed to evacuate from a 2007 tsunami because the 2006 tsunami was small [18].

1.2. Perceived Hazard Characteristics

There are many ways to characterize people's hazard perceptions [19–21], but two critical tsunami hazard perceptions are the respondents' perceived location inside or outside the tsunami inundation zone and their expectation of a local tsunami's first wave arrival time. Coastal residents' perceptions of their location in a tsunami zone are important because tsunami evacuation rates are approximately 90% in coastal zones but only 54–73% in inland zones [16]. People who know that they are in a tsunami zone have higher risk perceptions, are more likely to evacuate [22], and evacuate sooner [23–25]. However, many people do not know if they are in a hazard zone [26], even when they are shown a hazard map [27,28].

Coastal residents' beliefs about a local tsunami's first wave arrival time are also important because earlier arrival times decrease their expected evacuation preparation times [29]. However, there can be substantial differences within communities regarding expected first wave arrival times. Specifically, there was little difference between Christchurch New Zealand and Hitachi Japan in the percentage of respondents who expected a tsunami within 0.75 h, approximately 50% of the respondents in each community [25]. However, there were substantial differences in the percentages of respondents who expected a tsunami to arrive in the interval 1.00–1.75 h, a difference of approximately 25% points. Surprisingly, ref. [30] found that evacuation decisions were not significantly affected by people's expectations that a tsunami would occur, its estimated arrival time, or its expected damage.

1.3. Hazard Awareness and Emergency Preparedness

In many tsunami zones, hazard awareness is modest and preparedness is low [31]. By contrast, US Pacific Northwest coast communities have a relatively high level of awareness, but their level of tsunami preparedness has also been reported to be low [23]. Some studies have tested models of household preparedness for tsunamis [32,33] and the earthquakes that cause them [21,34–36]. These studies have examined predictors of household preparedness such as risk perception, hazard intrusiveness, personality characteristics (e.g., negative affect, fatalism, and optimism), trust in experts, and hazard experience [37]. However, few studies have examined the effects of that preparedness on tsunami response intentions and actual response. More recently, ref. [14] categorized tsunami emergency preparedness as informational preparedness and physical preparedness. Informational preparedness includes activities such as the receipt of hazard information in brochures and attendance at hazard education meetings [38], whereas physical preparedness consists of acquiring basic survival supplies [39]. Given the rapid onset of local tsunamis, residents should prepare a *grab-and-go* kit before an earthquake strikes so they can evacuate immediately [40]. In addition, evacuation is more likely to be successful if people have engaged in preimpact evacuation planning that involves identifying an evacuation destination, route, and travel mode [41], as well as practicing their evacuation route in response to a warning, drill, or personal curiosity [42].

1.4. Expected Tsunami Warning Sources

Coastal residents have strong expectations of being warned by social sources, especially official warnings [30], and few distinguish between distant and local tsunamis in their expectations of being warned by different sources [40]. For local tsunamis, people place greater reliance on sirens and broadcast channels than earthquake shaking [31,40], and even those who are aware of the potential for a tsunami shortly following an earthquake expect an official evacuation warning [43]. Indeed, there is mixed evidence as to the effectiveness of ground shaking as a cue to prompt tsunami evacuation [16], in part because many people are unable to correctly interpret a tsunami's environmental cues—long and strong earthquake shaking or sea-level drawdown [30]. For example, few people who observed any environmental cues of the 2004 Indian Ocean tsunami's onset recognized the significance of these cues [44]. However, many respondents in American Samoa (43%) were aware of earthquake shaking as an environmental cue, whereas few were warned by radio/TV broadcasts (15%) or village bells ringing (14%) [38]. Similarly, most people in Sulawesi were warned by earthquake shaking (42%) or seeing the tsunami wave (19%), but only a few were warned by broadcast media (10%), authorities (1%), or the Internet (1%) [45].

1.5. Expected Evacuation Decision and Evacuation Logistics

Consistent with the prevalence of milling as an immediate response to disaster warnings [7], only 11% of the respondents in [46] immediately evacuated or intended to do so. Instead, from 52% [38] to 85% [47] of those at risk attempt to obtain additional information. Moreover, people frequently perform evacuation preparation tasks immediately before departure [38,43,45,48] but expect to take little time to complete evacuation preparations. For example, ref. [22] found that their respondents only expected to complete a few evacuation preparation tasks (M = 3.1 of 10 items), but their expected evacuation preparation time (12 min) plus their expected travel time (8 min) would exceed their expected tsunami arrival time (18 min). Similarly, ref. [40] reported that most of their respondents expected to evacuate within 10 min and almost all of the rest expected to evacuate within 30 min. Although the percentage of respondents expecting to take each of six evacuation preparation actions was lower for a local tsunami (<1 h) than a distant tsunami (9–12 h), only 6% of the respondents would leave immediately without taking any preparatory actions. Nonetheless, there are cases in which people evacuate extremely rapidly, such as a finding that 69% of their respondents reached safety within 15 min, probably because 59% were able to evacuate to nearby high ground [45]. However, ref. [48] found that only 33% of their respondents evacuated within the recommended 10 min and [49] reported that only 66% of their respondents evacuated within 20 min.

Pedestrian evacuation is the recommended mode for tsunami response, but many people take cars even though the surge in traffic demand can cause traffic jams [48,50,51]. Indeed, some vehicles moved more slowly than pedestrians during evacuation from the 2011 Tohoku tsunami [52]. Accordingly, most residents (74%) on the east side of American Samoa evacuated by foot [53], as did the majority of evacuees in the 2004 Thailand [44], the 2011 Tohoku [54], and the 2018 Sulawesi [45] tsunamis.

By contrast, other studies report that most of their respondents evacuated in vehicles [38,43], although [22] reported that the percentage of their respondents who intended to evacuate by foot (39%) is almost the same as by car (38%). Moreover, [40] found that most respondents intended to evacuate by car for distant tsunamis but evacuation by foot and car were equally likely for a local tsunami. This preference for evacuating by cars can be explained by a variety of reasons including needing to travel a long distance to a safe location, evacuating additional people outside the household, maintaining mobility after evacuating, and having a heater in the vehicle [55]. However, there can be substantial differences between the expected behavior before a tsunami occurs and behavior during an actual tsunami; ref. [56] found that planned car use was 21% but actual use was 73%.

1.6. Demographic Variables

Studies of environmental hazards consistently find that some demographic variables predict emergency preparedness and response. However, the demographic variables that are significant predictors in one study often fail to be replicated in other studies, leading [57] to conclude that demographic variable have small and inconsistent correlations with hurricane evacuation, a conclusion also reached in a statistical meta analysis of hurricane evacuation [58] and a systematic review of North American studies of hazard adjustment adoption [59]. Nonetheless, it is important to assess demographic variables to determine if a study's sample is reasonably representative of that area's population.

1.7. Correlates of Expected Evacuation Decisions and Evacuation Logistics

In a study of actual evacuations, [15] found that evacuation clearance time was positively related to disaster knowledge, ocean proximity, and tsunami experience, but negatively related to household size, whereas [38] found that greater evacuation delay was positively correlated with later expected tsunami arrival and lower tsunami risk perception. In a report on evacuation expectations, ref. [14] reported positive correlations with emergency preparedness, self-efficacy, perceived tsunami knowledge, coastal proximity, female gender, younger age, and less difficulty walking, whereas expected evacuation preparation correlated negatively with coastal proximity, but positively with female gender and household size. The authors of [22] reported that evacuation expectation was positively correlated with perceived risk to self and perceived tsunami zone location, but negatively correlated with expected tsunami arrival time. Moreover, expected car evacuation was negatively related to emergency preparedness, homeownership, expected tsunami arrival time, and coastal proximity; expected foot evacuation was positively correlated with expected evacuation leadership and emergency preparedness. Finally, expected clearance time was negatively correlated with self-efficacy, car evacuation, income, and perceived tsunami knowledge, but positively correlated with foot evacuation, walking disability, and age. The authors of [29] found that the expected number of evacuation preparation tasks was positively correlated with expected evacuation preparation time, expected tsunami arrival time, and car evacuation, but negatively related to foot evacuation. Moreover, expected evacuation preparation time was positively correlated with expected evacuation travel time and tsunami arrival time. Finally, car evacuation was positively related, and foot evacuation was negatively related, to car ownership. All of these variables were uncorrelated with location (tsunami zone, home elevation, and ocean proximity), experience, and demographic variables.

1.8. Research Questions

Previous tsunami research and planning practice indicates that people in tsunami zones need to know about the hazard (e.g., first wave arrival time and inundation zone boundaries), sources from which they can expect to receive a warning (environmental cues and social sources), and protective action recommendations (e.g., pre-impact hazard mitigation and emergency preparedness actions; recommended evacuation modes, routes, and destinations). Thus, it is important to continue assessments of the degree to which coastal residents have addressed these issues. In addition, it is important to determine how these variables are related to each other and if they are related to demographic variables. These considerations lead to the following four research questions.

RQ1. What are CSZ residents' levels of hazard experience, perceived hazard characteristics, and emergency preparedness?

RQ2. What are CSZ residents' expectations about warning sources, evacuation decisions, and evacuation logistics?

RQ3. Are hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics correlated with each other?

RQ4. Are demographic variables related to hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics?

2. Materials and Methods

2.1. Sample

From August to September 2019, the Environmental Hazards Research Institute conducted an Internet survey of residents in three areas—Commencement Bay, Washington; Lincoln City, Oregon; and Eureka, California. The Commencement Bay sample comprises households in Fife, Tacoma, and Puyallup. The Lincoln City sample contains households from Lincoln City's Taft neighborhood south to Gleneden Beach. The Eureka sample comprises households from Samoa, Manila, and downtown Eureka south to Fields Landing.

The Marketing Systems Group produced a representative sample of 400 households in each community, 900 of which were asked to participate in an online survey. Following [60], the initial contact was a postcard to each household notifying them to expect a letter inviting them to participate in this study. This postcard was followed by the invitation letter explaining this study, its sponsorship, their rights as human subjects, the offer of $20 compensation for their participation, and procedures for logging onto this study's website. This invitation letter was followed at approximately 10 day intervals by a reminder postcard and a second invitation letter. Only 90 of the households completed valid questionnaires online for a response rate of 10%, so paper questionnaires were mailed to non-responding households from the initial sample plus an additional 300 households, all of whom were offered a $10 electronic gift card for their participation. Non-respondents to this initial contact were sent a reminder post card one week later. The mail survey yielded 128 valid questionnaires and, thus, a total of 221 responses from the Internet and mail surveys. After subtracting 147 undeliverable addresses from the total sample of 1200 households, the overall response rate is 21%.

2.2. Procedure

The questionnaire addressed respondents' expectations of being warned in six different ways about local and distant tsunamis, such as environmental cues (e.g., earthquake shaking and sea-level drawdown) and social sources (e.g., community sirens, NOAA Weather Radio, route alert, and commercial TV/radio). Ratings ranged from *Not at all likely* = 1 to *Extremely likely* = 5. The questionnaire also asked if they expected to evacuate during earthquake shaking, evacuate after shaking stopped, and engage in milling actions after the shaking stopped (e.g., contact peers, wait for an official warning, check TV/radio, check social media, check peer evacuations, and pack bags; *Not at all likely* = 1; *Extremely likely* = 5). The questionnaire also contained items addressing participants' emergency preparedness (portable radio and spare batteries, NOAA Weather Radio, stored food and water, 1st aid kit) and expected evacuation logistics. The latter comprised the expected number of minutes (a) after shaking stopped until the first tsunami wave arrived, (b) to prepare to leave the house, and (c) to travel from the house to a safe location, as well as the respondents' expected evacuation mode (e.g., vehicle, foot, or other) and whether they had already planned an evacuation route and destination.

The questionnaire also addressed seven aspects of respondents' current preparedness actions and expectations of future preparedness actions, the first of which asked whether they had practiced their evacuation routes in response to a tsunami warning, an evacuation drill, or personal curiosity (*Yes, already have; No, but will do; No, won't do*). The preparedness questions also asked about possession of preparedness items such as a portable radio with spare batteries and food and water for three days, as well as whether the respondent had a *grab-and-go* kit (*Yes, already have; No, but will get; No, won't get*). In addition, the preparedness questions asked whether the respondent had attended earthquake or tsunami meetings (*Yes; No, but I would attend one; No, and I would not attend one*), received earthquake or tsunami brochures (*Yes; No, but I would like to receive one; No, and I would like to receive one*), or taken any additional preparedness actions such as signing up for tsunami alerts or preparing a household emergency plan (*Yes, have done; No, but will do; No, won't do*). The last part of the questionnaire addressed people's tenure in their community and current residence, perceived location in a tsunami inundation zone, tsunami experience, homeownership, age, gender, marital status, household age composition, ethnicity, income, and education.

3. Results

As indicated in Table 1, the analyses for RQ1 (What are CSZ residents' levels of hazard experience, perceived hazard characteristics, and emergency preparedness?) show that 25% of the respondents had experienced a warning but no tsunami damage, whereas 9% had experienced a warning and did have tsunami damage. Moreover, 45% thought they were inside the tsunami zone and the mean time of first wave arrival would be 20 min. Many respondents had received an earthquake (43%) or tsunami (40%) brochure, but many fewer had attended earthquake (24%) or tsunami (19%) meetings. Nonetheless, they had 48% of the items in a 7-item emergency kit, 29% had a *grab-and-go* kit, and 25% had signed up for electronic tsunami alerts. Most respondents had planned an evacuation destination (69%) and route (70%), and some had practiced their evacuation route out of curiosity (34%), for a drill (16%), or in response to a tsunami warning (20%).

Table 1. Means (M), standard deviations (SD), and correlations among variables (shaded correlations significant at $p < .01$).

A

	Variable	**M**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Oregon	0.39	0.49	1														
2	Calif	0.36	0.48	−.60	1													
3	Education	4.47	0.96	.01	.05	1												
4	Income	2.63	1.37	.00	−.21	.36	1											
5	White	0.82	0.38	.06	.07	.01	−.09	1										
6	Married	0.46	0.50	.06	−.19	.13	.53	−.12	1									
7	Female	0.53	0.50	.09	−.12	.17	−.01	.01	.05	1								
8	Age	55.36	16.77	.25	−.22	.02	−.03	.05	.08	.02	1							
9	HomeOwn	0.69	0.49	.07	−.18	.01	.28	−.06	.28	.02	.26	1						
10	HomTen	11.42	12.49	−.17	.16	−.09	−.08	.03	.03	−.08	.39	.21	1					
11	CommTen	16.93	17.11	−.25	.13	−.15	−.09	.06	−.01	−.05	.30	.20	.70	1				
12	WrnNoDm	0.25	0.44	.09	.10	.03	−.03	.05	.01	.06	.20	.09	.24	.12	1			
13	WrnDm	0.09	0.29	.15	−.02	.02	.02	.01	.00	.00	.12	.12	.19	.12	.29	1		
14	PerZone	2.27	0.86	−.13	.30	−.10	−.08	−.08	−.10	−.08	−.09	−.04	.13	−.05	.01	.21	1	
15	ExTsuArriv	19.87	47.96	−.11	−.12	.05	.06	−.14	−.03	.14	.10	−.11	−.02	.00	−.07	−.05	−.01	1
16	EQBroch	0.43	0.50	.13	.09	.07	−.01	.08	.10	−.08	.12	.15	.14	.04	.16	.12	.06	−.14
17	TsuBroch	0.40	0.49	.22	.07	.05	.08	.02	.10	−.10	.10	.12	.01	−.07	.19	.14	.09	−.12
18	EQMeet	0.24	0.43	.09	.08	.09	.04	−.10	.00	−.14	.06	.03	.05	−.04	.23	.17	.15	−.10
19	TsuMeet	0.19	0.39	.10	.13	.08	.00	−.13	−.02	−.11	−.02	−.03	.02	−.08	.24	.05	.13	−.09
20	TsuAlert	0.25	0.43	.17	.08	.02	.02	−.11	.06	−.07	.04	.06	−.02	−.09	.31	.19	.12	−.11
21	HHEmPrep	0.48	0.50	.12	.01	.03	.04	.03	−.03	.06	.07	.13	.02	−.06	.21	.08	.06	−.08
22	GrabGoKit	0.29	0.45	.20	−.09	.05	.05	−.12	.08	.04	.15	.15	.01	−.06	.21	.13	.03	−.07
23	EvPracCur	0.34	0.48	.11	.01	.14	.08	−.09	.00	.07	.10	.07	.03	−.06	.21	.04	.02	.09
24	EvPracDrill	0.16	0.36	.02	.13	.02	−.08	.02	−.09	.01	.07	−.05	.13	.03	.15	.11	.03	−.07
25	EvPracWrn	0.20	0.40	.16	−.01	−.05	−.05	−.09	−.14	.00	.07	−.03	.12	.03	.36	.37	.01	−.07
26	PlanDestin	0.69	0.46	.18	.01	.11	.13	.02	.06	.00	.13	.08	.13	.12	.17	.14	.06	−.02
27	PlanRoute	0.70	0.46	.13	.09	.08	.08	−.03	.01	−.02	.18	.15	.17	.14	.24	.13	.08	−.04
28	SocWrnDis	3.24	1.06	.04	−.08	−.05	−.04	−.07	.03	−.12	.10	.07	.04	.00	.08	.09	−.13	.06
29	SeaWrnDis	3.01	1.43	.02	−.01	−.16	−.15	−.02	.00	.01	.01	−.01	.00	.08	−.10	−.03	−.07	.04
30	EQWrnDis	2.82	1.50	−.03	−.05	−.24	−.17	−.09	−.09	−.01	−.10	−.12	−.11	.00	−.14	−.03	−.08	.04
31	SocWrnLoc	3.17	1.06	.08	−.18	−.09	−.10	−.12	.00	−.05	.15	−.06	−.02	.01	.02	−.03	−.15	.13
32	SeaWrnLoc	3.45	1.44	.03	.04	.04	−.04	−.02	.01	.07	.07	−.03	−.01	.07	−.12	.00	.03	.03
33	EQWrnLoc	3.72	1.24	−.06	.18	.05	.02	−.04	.01	−.06	−.17	−.02	−.03	−.01	.05	.06	.20	.06
34	EvDuring	3.01	1.49	.18	−.08	.02	−.08	−.10	−.06	−.06	.09	.08	−.01	−.05	−.03	.18	.07	−.08
35	PstShkPrp	3.33	1.01	−.07	−.10	−.05	−.06	−.02	−.03	.05	−.10	−.10	−.14	−.08	−.16	−.12	−.11	.12
36	EvAfter	3.68	1.32	.21	−.04	.13	−.01	−.13	−.06	.02	.05	.05	−.01	−.11	.08	.09	.19	.00
37	EvPrpTim	10.24	8.30	−.15	−.12	.04	.10	−.06	.15	.09	.06	.01	.06	.02	−.06	−.03	−.10	.14
38	FootEvac	0.20	0.40	.23	−.04	.14	.00	−.06	.08	−.01	.09	.08	.03	.02	.20	.12	.01	−.09
39	CarEvac	0.54	0.50	−.08	−.04	−.09	−.03	.03	−.05	.07	−.10	−.14	−.07	−.07	−.11	−.01	.01	.12
40	WontEvac	0.10	0.30	.00	−.01	.01	.07	.08	.01	.00	.09	.12	.05	.00	.02	−.06	−.16	−.01
41	EvTrvTim	18.84	73.28	−.11	−.08	.03	.07	−.18	.08	.11	−.10	.03	−.09	−.03	.14	−.04	−.15	.03

B

	Variable	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
16	EQBroch	1																	
17	TsuBroch	.86	1																
18	EQMeet	.50	.48	1															
19	TsuMeet	.46	.48	.79	1														

Table 1. *Cont.*

B

	Variable	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
20	TsuAlert	.33	.35	.40	.40	1													
21	HHEmPrep	.34	.34	.40	.37	.35	1												
22	GrabGoKit	.26	.26	.42	.42	.36	.45	1											
23	EvPractCur	.32	.35	.37	.44	.32	.34	.35	1										
24	EvPracDrill	.20	.21	.38	.47	.19	.19	.29	.42	1									
25	EvPracWrn	.12	.23	.26	.33	.28	.24	.30	.45	.54	1								
26	PlanDestin	.24	.27	.26	.24	.26	.41	.26	.28	.21	.32	1							
27	PlanRoute	.31	.32	.27	.29	.29	.47	.28	.37	.23	.31	.77	1						
28	SocWrnDis	.16	.14	.12	.15	.15	.25	.21	.19	.21	.25	.14	.22	1					
29	SeaWrnDis	.01	.00	−.05	−.01	.01	.14	.11	.10	.15	.19	.01	.05	.43	1				
30	EQWrnDis	−.09	−.11	−.08	.00	.01	.00	.03	.02	.14	.20	−.01	−.03	.34	.57	1			
31	SocWrnLoc	.05	.04	.08	.05	.11	.16	.09	.12	.11	.21	.15	.21	.53	.32	.28	1		
32	SeaWrnLoc	.08	.09	−.02	.04	−.02	.09	.17	.11	.15	.15	.18	.15	.26	.54	.18	.38	1	
33	EQWrnLoc	.19	.24	.16	.19	.15	.07	.16	.14	.23	.18	.15	.12	.28	.31	.19	.17	.42	1
34	EvDuring	.06	.05	.10	.11	.20	.07	.18	.18	.12	.20	.15	.14	.16	.08	.06	.16	.17	.11
35	PstShkPrp	−.12	−.18	−.13	−.13	−.08	−.10	−.12	−.09	−.12	−.03	−.10	−.09	.14	.08	.18	.34	.07	−.18
36	EvAfter	.15	.17	.22	.21	.22	.23	.29	.29	.26	.22	.22	.27	.22	.11	.08	.06	.14	.18
37	EvPrpTim	−.23	−.25	−.18	−.19	−.21	−.16	−.22	−.06	−.18	−.03	−.12	−.22	−.18	−.18	−.10	−.02	−.18	−.22
38	FootEvac	.31	.35	.29	.32	.22	.13	.24	.16	.30	.21	.28	.22	.00	−.03	−.03	−.08	.06	.21
39	CarEvac	−.32	−.30	−.23	−.27	−.10	−.10	−.23	−.19	−.24	−.14	−.23	−.19	.03	−.01	.05	.01	−.02	−.12
40	WontEvac	.00	.00	−.05	−.05	−.06	.03	−.05	−.02	.07	.04	.01	−.07	−.10	−.07	−.06	−.07	−.07	−.08
41	EvTrvTim	−.12	−.12	−.09	−.08	.06	.03	.07	.06	−.07	.10	−.01	−.01	.01	.10	.10	.15	−.03	−.07

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	Variable	34	35	36	37	38	39	40
34	EvDuring	1						
35	PstShkPrp	0.06	1					
36	EvAfter	0.53	0.02	1				
37	EvPrpTim	−.10	0.28	−.19	1			
38	FootEvac	0.17	−.25	0.34	−.14	1		
39	CarEvac	−.01	0.24	−.08	0.2	−.54	1	
40	WontEvac	−.14	−.11	−.29	−.05	−.17	−.36	1
41	EvTrvTim	0	0.08	−.10	0.28	−.07	0.09	−.02

HomeOwn = homeowner, HomTen = tenure in current residents, CommTen = tenure in current community, WrnNoDm = previous tsunami warning, no damage, WrnDm = previous tsunami warning, experienced damage, PerZone = perceived location inside tsunami zone, ExTsuArriv = expected tsunami arrival time, EQBroch = received earthquake brochure, TsuBroch = received tsunami brochure, EQMeet = attended earthquake meeting, TsuMeet = attended tsunami meeting, TsuAlert = signed up for electronic tsunami warning, HHEmPrep = household emergency preparedness level, GrabGoKit = has a *grab-and-go* kit, EvPracCur = evacuation route practiced out of curiosity, EvPracDrill = evacuation route practiced in a drill, EvPracWrn = evacuation route practiced during a tsunami warning, PlanDestin = planned an evacuation destination, PlanRoute = planned an evacuation route, SocWrnDis = expect social warning for distant tsunami, SeaWrnDis = expect sea level warning for distant tsunami, EQWrnDis = expect earthquake warning for distant tsunami, SocWrnLoc = expect social warning for local tsunami, SeaWrnLoc = expect sea level warning for local tsunami, EQWrnLoc = expect earthquake warning for local tsunami, EvDuring = will evacuate during earthquake shaking, PstShkPrp = evacuation preparations after shaking, EvAfter = will evacuate after earthquake shaking, EvPrpTim = expected evacuation preparation time, FootEvac = will evacuate on foot, CarEvac = will evacuate by car, WontEvac = will not evacuate, and EvTrvTim = expected evacuation travel time.

The results for RQ2 (What are CSZ residents' expectations about warning sources, evacuation decisions, and evacuation logistics?) show that, for a distant tsunami, respondents had stronger expectations of warnings from social sources than from sea-level drawdown or earthquake shaking (M = 3.2, 3.0, and 2.8, respectively), whereas the pattern was reversed for a local tsunami (M = 3.2, 3.5, and 3.7, respectively). The respondents rated immediate evacuation as moderately likely during earthquake shaking (M = 3.0) but more likely after shaking stopped (M = 3.7); only 10% expected to not evacuate. The average level of expected post-shaking evacuation preparation was moderately high (M = 3.3 of 5 actions), but their expected preparation time was relatively short (M = 10 min). The majority expected to evacuate by car (54%) rather than on foot (20%) and take 19 min to reach safety.

The results for RQ3 (Are hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics correlated with each other?) show that experiencing a warning but no damage is more strongly correlated with preparedness actions (average correlation—$\bar{r}$ = .22) than are warning with damage ($\bar{r}$ = .14) and perceived zone ($\bar{r}$ = .07). However, they have non-significant correlations with expected warning sources, tsunami arrival time, evacuation during shaking, evacuation preparation, evacuation after shaking, evacuation preparation time, foot evacuation, car evacuation, and travel time ($\bar{r}$ = −.01).

Moreover, those who have received hazard brochures are more likely to have attended hazard awareness meetings ($\bar{r}$ = .48) and both sources of hazard information are correlated with emergency preparedness actions ($\bar{r}$ = .36) and evacuation preparedness ($\bar{r}$ = .29). They are also more likely to expect earthquake shaking as a local tsunami warning source, evacuate after shaking ends, take less time in evacuation preparation, and evacuate on foot rather than in cars ($\bar{r}$ = .20, .19, −.21, .32, and −.28, respectively). The three emergency preparedness actions are also strongly correlated ($\bar{r}$ = .39) and those who have engaged in these actions are more likely to expect social warning sources for distant tsunamis, evacuate after shaking ends, take less time after shaking in evacuation preparation, and evacuate on foot ($\bar{r}$ = .20, .25, −.20, and .20, respectively). The correlations for general household emergency preparedness are somewhat lower than those for signing up for tsunami alert and having a *grab-and-go* kit, possibly because some of those who have taken general emergency preparedness actions are responding to earthquake threat rather than tsunami threat. The evacuation preparedness actions are also strongly correlated ($\bar{r}$ = .39) and those who have engaged in these actions are more likely to expect social warning sources for distant tsunamis, evacuate after shaking ends, and evacuate on foot rather than in cars ($\bar{r}$ = .20, .25, .23, and −.20, respectively).

The expected warning sources are also strongly correlated ($\bar{r}$ = .35), but the correlations among the warning sources for distant tsunamis ($\bar{r}$ = .45) are stronger than those for local tsunamis ($\bar{r}$ = .32). Those who practiced their evacuation route in response to a warning were accurate in being more likely to expect warnings of a distant tsunami from social sources (r = .25), but they also expected warnings from sea-level drawdown (r = .19), which is possible but not certain. In addition, they erroneously expect to be warned of distant tsunamis by earthquake shaking (r = .20) and local tsunamis by social sources (r = .21). However, expected tsunami arrival time is not significantly related to any of the other variables ($\bar{r}$ = −.01). Finally, those who plan to engage in more post-shaking evacuation preparation activities expect to take more time to prepare and evacuate in cars rather than on foot (r = .24, .24, and −.25, respectively). Those who plan to evacuate after shaking stops plan to take less time in evacuation preparation (r = −.19) and instead evacuate on foot (r = .34). Those who expect to take more time in post-shaking evacuation preparation expect to take cars (r = .20) and have longer evacuation travel times (r = .28).

The results for RQ4 (Are demographic variables related to hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics?) show that the demographic variables have an average correlation with other variables of $\bar{r}$ = .01. Of the 330 (= 30 × 11) correlations, only 7 (2.1%) are statistically significant and there is no obvious pattern to those correlations.

4. Discussion

4.1. Results for RQ1

The results for RQ1 (What are CSZ residents' levels of hazard experience, perceived hazard characteristics, and emergency preparedness?) indicate that the respondents have a relatively low level of experience with false alarms (25%) and an even lower level of experience with tsunami damage (9%). This low level of experience is unsurprising because the respondents' average age (55 year) is almost exactly the same as the time since the tsunami caused by the 1964 Great Alaska earthquake struck this area. The expected times of first wave arrival for a local tsunami (75% expect this wave within 15 min) are somewhat more accurate than previous CSZ data, which indicated that only 40–50% of the respondents expected a local tsunami's first wave to arrive this soon [61–63]. These CSZ residents' expected first wave arrival times are about as accurate as respondents who had an average estimate of M = 18 min [22]. However, these CSZ residents expected more rapid onset than Indonesian respondents, only 45% of whom expected the first wave within 20 min and 42% who expected 1 h or more [13]. Additionally, unlike these CSZ residents, only 29% of Caribbean respondents thought a local tsunami could arrive in less than 1 h [64].

CSZ residents' receipt of earthquake (43%) and tsunami (40%) brochures is lower than the 62% of Washington coastal residents that [23] reported had seen tsunami hazard zone maps or the 76% who had received information about tsunami hazards. However, the CSZ residents' rate of brochure receipt is similar to the 55% reported by [65] and much higher than that reported by [43], who found that few respondents recalled receiving a tsunami brochure that was included in their utility bills and only one of whom had read it.

CSZ residents' 24% earthquake meeting attendance rate is the same as the 24% in American Samoa, but tsunami meeting attendance (19%) is slightly lower (28%) [38]. The fact that access to these information sources is less than 100% is not necessarily a problem because the percentage of respondents in American Samoa who knew that an earthquake could cause a tsunami was larger than the percentage who had attended earthquake or tsunami meetings [38]. The conclusion that tsunami information is transmitted informally through peer networks is consistent with other research showing that people can learn the correct interpretation of environmental cues through peer communication. For example, one community's oral history, coupled with continuous residence in the area over the years, produced a high level of adaptive response [66]. There are similar findings regarding oral transmission of knowledge about tsunami hazard in the Solomon Islands [67].

The data on respondents' emergency preparedness are difficult to compare with other studies because lists of preparedness items vary substantially across studies. In general, however, CSZ respondents' possession of first-aid kits, portable radios, and food and water are within the ranges reported in a summary of earthquake preparedness surveys [39]. Compared to other tsunami preparedness studies, the percentages of CSZ households having a 3 day supply of stored food and water is lower than the 53–73% reported in [61–63]. The CSZ respondents' low rate of possessing NOAA Weather Radios (28%) is almost identical to the 29% reported in [32] and 30% reported in [33]. This, together with their low rate of subscription to National Tsunami Warning Center electronic alerts (25%), suggests that many people would not receive a sufficiently timely tsunami warning from authorities.

The CSZ respondents' possession of tsunami *grab-and-go* kits (29%) is similar to the 30% reported in [32], but lower than the 39% rate reported in [33] or the 44% reported in [68], but is within the 19–40% range from [61–63]. All of these samples were better prepared for tsunami evacuation than the respondents in [43], none of whom had *grab-and-go* kits. The CSZ respondents' 16% participation rate in tsunami evacuation drills is about the same as the 13% reported by [32] and the 19% by [69], but not as high as the 40% by [33]. The CSZ respondents' participation in tsunami evacuation drills is within the range reported by [61–63], who found that 1–41% of their respondents had participated in evacuation drills, and is much lower than the 44% reported in [13] or 49% in [69]. The CSZ respondents are better prepared for a tsunami evacuation than the respondents in [43], none of whom knew their area's official tsunami evacuation routes.

The CSZ data on planned evacuation routes (70%) and destinations (69%) are somewhat better than the finding that only 51% of their respondents knew what evacuation route they would take [65] and the finding that only 50% of their respondents were able to identify their evacuation destination [68]. The CSZ respondents have much more specific plans than those of [70], who reported that only 20% of their respondents knew how to evacuate if a tsunami threatened.

4.2. Results for RQ2

The findings for RQ2 (What are CSZ residents' expectations about warning sources, evacuation decisions, and evacuation logistics?) indicate that many coastal residents are unrealistic in their expectations of official warnings for a local tsunami (M = 3.17), which are almost identical to those for a remote tsunami (M= 3.24). This is troubling because official warnings from the National Tsunami Warning Center for a remote tsunami are highly likely, even for tsunamis generated near Alaska that take over 2 h to strike the CSZ. Indeed, official warnings would be received much faster than the 8 h it took to notify 94% of the Mauritius population of the 2004 Indian Ocean tsunami [71] and probably even faster than the 2 h it took to notify 96% of the Australian coastal population of the 2007 Solomon Islands tsunami [72]. Moreover, recent technology can substantially speed the dissemination of tsunami warnings. For example, the Indonesian tsunami hazard agency's tweets of a 2012 tsunami warning reached 4 million direct and indirect Twitter followers within 15 min of the original tweet [73]. Finally, the data on expected warning by earthquake shaking are concerning for two reasons. First, the rating for a local tsunami (M = 3.72), though significantly higher than the rating for a distant tsunami (M = 2.82), is far below the appropriate rating of 5; this means that not enough CSZ residents recognize long and strong earthquake shaking as a reliable cue for a tsunami. Second, the rating for a distant tsunami is far above the appropriate rating of 1; this means that too many CSZ residents expect to feel shaking from a distant tsunami.

The data on evacuation preparations after the shaking stops (M = 3.3 of 5 items) are consistent with previous disaster research showing that households delay their evacuations after receiving warnings [74,75]. Even in the case of a rapid onset disaster such as a local tsunami, people commonly try to confirm warnings, warn peers, plan how to respond, collect family members and pets, secure property, pack for the trip, and assist others in evacuation [38,43,48,68,71,72]. Of course, some actions can only be taken during the emergency (e.g., collecting family members and pets, securing property, and assisting others in evacuation). However, people can reduce the number of last-minute evacuation preparations by advance training (learning that long and strong earthquake shaking does not need confirmation by other sources), advance preparation (preparing *grab-and-go* kits before an event), and advance planning (selecting an evacuation mode, route, and destination before an event; warning peers *while* evacuating rather than before). In addition, people can respond appropriately to the situational time constraints by setting priorities for deciding which actions can be safely taken for a remote tsunami and which must be omitted for a local tsunami. For example, ref. [61–63] found that only 78% of their respondents expected to take personal belongings with them for a distant tsunami, but only 36% of them expected to do so for a local tsunami.

The CSZ data on expected preparation times are consistent with those of [50], who found that 7% of their respondents left immediately, 52% left within 5 min, 77% left within 10 min, 92% left within 15 min, 94% left within 25 min, and 99% left within 30 min. Of course, it is important to recognize that people might not be able to accurately estimate their departure times. Specifically, an evacuation expectations survey found that 62% of the respondents expected to leave within 10 min [40], but a later survey found that only 29% later took less than 10 min during an actual tsunami, only 45% took less than 30 min, and only 56% were gone within 3 h [48].

Consistent with the CSZ data indicating that 61% expect to evacuate by car and 23% by foot, ref. [29] reported that 75% expect to evacuate by car. More generally, the CSZ results are consistent with the finding of an overwhelming preference for evacuation by car [16]. Nonetheless, it is important to recognize that there are differences among communities. For example, vehicular evacuation (82%) was more than four times as popular as pedestrian evacuation (18%) in one part of American Samoa [38], but pedestrian evacuation (75%) was more popular than vehicular evacuation (26%) in a different part of the island [53]. Sometimes the relative preference for car and foot evacuation is due to differences in available transportation modes. For example, only a few Indonesian respondents expected to evacuate by car (14%) or other means (22%) rather than on foot (35%) or motorcycle (35%) because of the corresponding prevalence of motorcycles in normal transportation [13]. In addition, it is important to be aware that there might be disparities between expected and actual evacuation transportation modes. By contrast to the 22% who expected to evacuate by car in a 2015 survey, ref. [48] found that 62% of the respondents actually did evacuate by car and only 7% left on foot in response to a later tsunami warning. Conversely, ref. [76] found that, by contrast to the data from an earlier evacuation expectations survey in which 57% of the respondents expected to evacuate on foot and 21% expected to evacuate by car, 73% of them actually evacuated on foot and 18% actually evacuated by car.

The clearance times inferred from the CSZ data (10 min for preparation and 19 min for travel = 29 min for clearance) are much longer than the results of a tsunami evacuation expectations study of Japanese coastal residents. The authors of [76] reported that 64% of their respondents expected to reach safety (i.e., clearance time) within 10 min, and 87% expected to reach safety within 18 min. Similarly, ref. [29] reported an average expected travel time M = 8 min. Of course, expected travel times might be erroneous for both foot and car evacuations. Thus, research is needed to assess how long it takes to evacuate, given empirical walking speeds [77], whereas other research needs to assess actual walking speeds in tsunami evacuation drills [41] or in single-person evacuation drills [76,78].

4.3. Results for RQ3

The findings for RQ3 (Are hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics correlated with each other?) are partially consistent with previous research. Contrary to [15], CSZ residents' tsunami experience does not predict evacuation decisions or any aspects of evacuation logistics other than expected foot evacuation. Moreover, contrary to [38], expected preparation tasks and preparation time are not significantly correlated with expected tsunami arrival time. However, partially consistent with [14], post-shaking evacuation expectation is significantly correlated with perceived tsunami zone and many emergency preparedness variables (earthquake and tsunami meetings, signups for tsunami alerts, household emergency preparedness, preparation of a *grab-and-go* kit, and evacuation planning and practice), but not any demographic variables. Additionally, partially consistent with [22], post-shaking evacuation expectation is positively correlated with perceived tsunami zone location and expected foot evacuation, but not expected tsunami arrival time. Also partially consistent with [22], expected car evacuation is negatively related to most emergency preparedness indicators, but not homeownership or expected tsunami arrival time, and expected foot evacuation is positively correlated with emergency preparedness. However, mostly inconsistent with [22], expected travel time only has a significant correlation with expected evacuation preparation time. Finally, partially consistent with [29], the number of expected evacuation preparation tasks is positively correlated with expected evacuation preparation time and car evacuation, and negatively related to foot evacuation, but unrelated to expected tsunami arrival time. Additionally, partially consistent with [22], expected evacuation preparation time is positively correlated with expected evacuation travel time, but not expected tsunami arrival time. As with [29], all of these evacuation logistics variables are uncorrelated with location (tsunami zone, home elevation, and ocean proximity), experience, and demographic variables.

4.4. Results for RQ4

The findings for RQ4 (Are demographic variables related to hazard experience, perceived hazard characteristics, emergency preparedness, expected warning sources, expected evacuation decision, and expected evacuation logistics?) are consistent with reviews of hurricane evacuation [57,58] and hazard adjustment adoption [59] that have concluded that the effects of demographic variables on behavioral variables are small and inconsistent across studies.

4.5. Study Limitations

As noted in [79], a response rate (RR) such as this study's 21% often raises concerns about the representativeness of the sample. However, survey RRs currently average less than 10% [80], which can be found in some hazards surveys—8% RR in [81] and 2% RR in [82]. Thus, this survey's RR exceeds the current average. Second, a low RR only implies response bias if questionnaire responses significantly correlate with demographic variables, but this is not the case for general attitude surveys [83,84] or specifically for surveys of evacuation [57,58] and preparedness [37,59]. Moreover, representative results for means and proportions can even be obtained with RRs as low as 10% [85]. An additional limitation, as noted in [48,76], is that respondents' expected behavioral responses can differ from their actual behavioral responses when a disaster strikes but there is, nonetheless, some consistency between consistency between expected and actual responses [58,86], so there are reasons to continue reliance on studies of expected response. Specifically, even if behavioral expectations studies do not perfectly predict actual behaviors such as evacuees' transportation mode choices, they can make a valuable contribution to understanding the reasons why people expect to choose those behaviors.

5. Conclusions

CSZ residents have relatively low rates of receipt of hazard brochures and participation in hazard awareness meetings—less than 50% on all four measures. They also have insufficient levels of emergency preparedness—25–50% on three types of measures. Although the CSZ respondents have more emergency preparedness items than has been reported in some studies of earthquake preparedness, it is lower than in other studies and—in any event—not adequate for disaster demands. To address residents' reservations about adopting some of the emergency preparedness measures, emergency managers should engage coastal residents in hazard education sessions that ask participants to describe their perceptions of the obstacles to increasing emergency preparedness. For example, emergency managers might mention an item such as a three day supply of non-perishable food and ask participants to indicate how many think that costs too much, takes too much time and effort, takes specialized knowledge and skill, takes specialized tools or equipment, or takes too much cooperation with other people [6]. They could then ask if other audience members know a way to overcome those obstacles.

In addition, these CSZ residents had inappropriate beliefs about warning sources for local tsunamis—placing too much reliance on social warnings and insufficient reliance on earthquake shaking. Emergency managers should address such erroneous beliefs by explaining the importance of recognizing earthquake shaking as an environmental cue for local tsunamis and the difficulty—if not the impossibility—of officials broadcasting evacuation warnings via TV and radio within the 15 min that it would take for a tsunami to strike after a CSZ earthquake. Of course, any delays in warning transmission through broadcast media could be overcome if all CSZ residents possessed NOAA Weather Radios or subscribed to National Tsunami Warning Center electronic alerts, but these are only 28% and 25% of the respondents, respectively. Updates to the Wireless Emergency Alert (WEA) system that are currently being implemented will allow 360 character warnings to be broadcast (www.weather.gov/media/wrn/WEATsunamiFactSheet.pdf, accessed on 15 April 2022). However, the possibility that a CSZ earthquake could cause some warning transmission failures (e.g., cell tower power loss or toppling due to landslides or soil liquefaction) means that emergency managers should remind coastal residents of the need to know that earthquake shaking is an important cue to tsunami onset.

CSZ residents also have inappropriately strong expectations of evacuation during shaking and inappropriately strong expectations of engaging in "milling" actions (especially checking TV/radio, social media, peers) immediately after shaking stops. The large number of milling actions is consistent with the finding that few respondents have *grab-and-go* kits. However, this lack of evacuation preparedness seems inconsistent with the data showing that the respondents expect to take 10 min or less to prepare to evacuate.

This conflict between the expected number of evacuation preparation tasks and the short estimate of evacuation preparation time suggest that the respondents are vulnerable to the "planning fallacy"—underestimating the amount of time that it takes to complete a series of tasks [87]. Emergency managers can address this issue by encouraging people to conduct household evacuation preparation drills in which one person announces a start time and the other household members perform the tasks they expect to complete in preparation for evacuation. After everyone has completed their tasks, the timer informs everyone how long the preparations took in comparison to the expected arrival time for the first tsunami wave. If, as is likely, preparation time estimates have been significantly underestimated, coastal residents should prepare *grab-and-go* kits to speed their departure.

Although approximately 70% of the respondents have planned their evacuation routes and destinations, only a minority have actually practiced their evacuation routes. This might be why they have very short estimates of evacuation travel times. To increase the accuracy of coastal residents' estimates of evacuation travel times, emergency managers should recommend that households conduct evacuation travel time drills in which all household members travel to their expected safe destination using their expected travel mode (e.g., by car). In addition, they should also conduct an evacuation travel time drill using an alternate travel mode (e.g., on foot). Since evacuation preparation times and evacuation travel times will vary by time of day and day of week, these drills should be conducted according to these expected variations in circumstances. Coastal residents can compare the times from evacuation preparation drills and the evacuation travel time drills to the expected time of tsunami arrival to see if there are any situations in which their households cannot reach safety in time. If such situations can occur, households can revise their evacuation preparation checklists, use different travel modes, or choose different evacuation routes.

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