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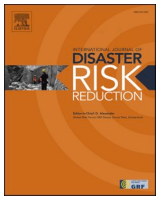

Tsunami awareness and preparedness in Aotearoa New Zealand: The evolution of community understanding

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ABSTRACT

After catastrophic events such as the 2004 Indian Ocean tsunami and the 2011 Great East Japan earthquake and tsunami there is a clear need for vulnerable countries like Aotearoa New Zealand to get prepared for tsunami. In the last ten years, the New Zealand government initiated major efforts to raise awareness of tsunami risk among coastal residents. This study explores tsunami awareness, preparedness, and evacuation intentions among residents of the East Coast of the North Island in a 2015 survey. The ten chosen locations also participated in a tsunami survey in 2003, with results demonstrating that tsunami awareness rose in the twelve years between the surveys. The 2015 survey also included questions on preparedness and intended action. Even though coastal residents know they live in a tsunami prone area, preparedness is relatively low and high expectations of a formal warning remain, even for a local source tsunami scenario. Furthermore, survey respondents had unrealistic ideas of evacuation procedures. When asked about their evacuation intentions, respondents intended to undertake a number of different actions before evacuating their homes, which could cause significant delays in the evacuation process. Most respondents were also reluctant to evacuate on foot and prefer using their vehicles instead, which could create dangerous traffic congestion. These surveyed intentions are consistent with a study of actual evacuation behaviours in the subsequent 2016 Kaikōura earthquake and tsunami, providing validation for the survey indicators. This paper identifies the procedures least understood by the public and offers some solutions to improve tsunami preparedness.

1. Introduction

The 2004 Indian Ocean tsunami triggered a sudden growth in international awareness of tsunami risk, especially for Pacific countries facing a high probability of tsunami. Tsunami risk can be defined as "the probability of a particular coastline being struck by a tsunami multiplied by the likely destructive effects of the tsunami and by the number of potential victims" [1]. Thus, to prevent a catastrophe caused by a tsunami, it is essential to work together with the exposed population (i.e., people living and working along or visiting the coast) to decrease the risk. Since little can be done to reduce the causes of tsunami hazards *per se*, attention should focus on mitigation and raising knowledge and levels of community preparedness to reduce and manage risk.

It is important to appreciate the complementary nature of structural mitigation and preparedness. For example, Japan, which was impacted by the 2011 Great East Japan earthquake and tsunami, had well-developed structural mitigation measures (e.g., sea walls). However, the subsidence that accompanied the 2011 earthquake was not anticipated and the walls were thus over-topped by the tsunami that ensued. Community preparedness to deal with the consequences of tsunami is therefore essential, particularly in places like New Zealand where the cost of coastal mitigation defences may not be feasible.

Aotearoa New Zealand sits on the boundary of the Pacific and Australian tectonic plates and therefore is exposed to several geological hazards including tsunami. However, New Zealand has not experienced a widespread and significantly damaging tsunami since European settlement in the 1800s. Consequently, the public's tsunami awareness is relatively low [2–6]. Since 2004, however, tsunami hazards have been the subject of particular focus by emergency managers in New Zealand. The National Emergency Management Agency (NEMA), formerly the

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Ministry of Civil Defence & Emergency Management (MCDEM), commissioned two science reports from GNS Science [7,8], one on the magnitude and scale of the threat (known as the "Hazard report"; Berryman et al., 2005; [9]), and the other on what people need to do to prepare (the "Prevention report"; [10]). NEMA has since been engaged in a renewal of its prevention strategy, with the core mission "to shift New Zealanders from apathetic awareness to total preparedness, resilience, self-responsibility and community responsibility" [11].

This paper draws from data from two public surveys, and discusses the change in the public's tsunami awareness between 2003 and 2015 and current levels of preparedness and evacuation intentions, to help identify what efforts need to be provided to make New Zealanders fully aware and prepared for a potential large tsunami.

1.1. Tsunami hazard and mitigation in New Zealand

In New Zealand, tsunami hazard is usually explained in terms of tsunami sources: the geographical areas where tsunami are generated, most of the time by a very large earthquake (>magnitude 7.5). There are three main types of tsunami sources for New Zealand: distant, regional, and local ([9]; see Fig. 1). Distant tsunami sources are those located thousands of kilometres away, across the Pacific Ocean (e.g., South America, Cascadia subduction zone in North America, Japan). Tsunami waves triggered by a distant source earthquake would generally arrive 9–12 hours after the originating event. A recent example was a tsunami warning on September 17, 2015 after a magnitude 8.3 earthquake in Chile [12]. Although the warning was cancelled, unusual sea behaviour along New Zealand's coastline was recorded during the 24 h following the earthquake.

A regional source tsunami would be triggered by an earthquake in the south western part of the Pacific (e.g., along the Kermadec or Tonga trench). In this case, the time interval between the earthquake event and the tsunami in New Zealand would be much shorter, between one and 3 h. Finally, a local source tsunami is generated from earthquakes directly off New Zealand's coast; the Hikurangi subduction zone which runs to the east of the North Island poses the highest risk. Tsunami generated locally could hit the closest parts of the coast within minutes, and a large stretch of coastline within 1 h.

The time interval before the first waves arrive determines whether or not an official warning can be issued by NEMA [13]. For distant tsunami which takes several hours to reach New Zealand, it is likely that there will be ample time for an official warning. It is more uncertain whether an official warning could be issued for regional tsunami, but it is still possible depending on the location of the triggering earthquake. However, for local tsunami, it is almost certain that there would not be time for an official warning, especially for those located on the area of coast closest to the earthquake. Exposed populations would therefore need to rely on natural signs only, of which the most identifiable one is the earthquake shaking itself, and may be coupled with unusual behaviour by the sea (e.g. the sea receding). This makes local tsunami the most concerning and dangerous threat, since survival of the exposed population requires individuals to recognise natural warnings and quickly take appropriate actions to evacuate and protect themselves. This response requires a high degree of tsunami risk awareness and knowledge of correct actions.

Although no widespread and significantly damaging tsunami have occurred since 1840, a few noticeable events which generated a run-up[1] on New Zealand's coast of 1 metre or more were identified since the 19th century [9,14]. Less than a metre run-up is considered as low risk because it can cause limited damage onshore; such an event may only be detected through marine sensors but can still cause dangerous currents and damage to coastal infrastructure. At least 25 tsunami with a run-up greater than a metre occurred between 1831 and 2012, which is more than one tsunami per decade [14]. The biggest tsunami run-up ever measured in New Zealand was about 15 m high, in Hawke's Bay in 1931 due to a landslide. This tsunami was highly localized in an area with little infrastructure and therefore caused no major damage. As a comparison, the maximum credible tsunami run-up for which emergency managers are now preparing is about 35 m high [15].

A Tsunami Working Group (TWG) was established in 2007 by NEMA"to coordinate and support national efforts in the development of a comprehensive tsunami risk management." [7,8]. The Working Group defined four keys areas for advancement in getting prepared: (1) Assessing the hazard and the risk for New Zealanders, (2) developing a warning system, (3) planning for response, and (4) raising awareness of tsunami risks and what to do.

From there, NEMA started promoting information about what to do if a tsunami was about to hit New Zealand. The most important message is that an earthquake lasting longer than a minute **or** during which it is difficult to stand should be considered as the first tsunami warning and requires an immediate evacuation of all coastal areas [16]. This has led to the development of the educational messaging "Long or Strong, Get Gone", which NEMA promotes via multiple communication channels [17]. In the meantime, people are encouraged to plan ahead for an emergency evacuation and to prepare a household plan, an evacuation itinerary, and "grab-and-go" emergency kits [18].

Besides raising awareness, considerable emphasis has been placed on tsunami hazard mitigation in the last ten years. Modelling of tsunami hazard zones is progressing for the most exposed coastal locations [16]. At the community scale, tsunami evacuation zone signs (Fig. 2) and billboards are being installed. Some communities showed their ability to innovate in collaboration with Civil Defence and Emergency Management (CDEM) groups, developing new ways to communicate risk, such as the blue line project of Island Bay, Wellington ([19]; Johnston et al., 2017). This project involved painting blue lines on the roads at the hazard's modelled maximum extent, to show where people would likely be safe in case of tsunami.

The first discussion about a possible tsunami warning system for New Zealand began just after the 1960 tsunami which was triggered by a powerful magnitude 9.5 earthquake off the Chilean coast [3]. This led to an arrangement with the Pacific Tsunami Warning Center (PTWC) based in Hawaii, which delivers warnings to New Zealand when a tsunami is identified across the Pacific Ocean. GeoNet was launched in 2001 to monitor geological hazards for New Zealand [21], followed by the National Geohazards Monitoring Centre in 2018. Its role is to detect earthquakes and tsunami triggered locally, in order to shorten time for an alert transmission to NEMA. Once the alert is given, the responsibility of disseminating the warning to the population falls under the CDEM regional agencies for their own jurisdictions, according to the 2002 CDEM Act [3], which leads to some cross-regional inconsistencies in dissemination and communication.

1.2. Theoretical background

High risk awareness, while not sufficient to motivate behaviour alone, is typically a prerequisite for improving disaster preparedness [22–25]. Ignorance of a potential risk can result in no, or delayed, mitigation actions and a higher casualty rate when disasters strike. This was illustrated during the 2004 Indian Ocean tsunami; most of the people died because they were unaware that a tsunami could occur where they lived and as a result did not know how to protect themselves [24,26–28]. There are notable exceptions; the population of Simeulue Island immediately fled toward the hills after the earthquake, since locals had the historical memory of a tsunami in 1907 that killed 70% of the island's population [26,29]. As a consequence, the casualty rate in Simeulue in 2004 was much lower than in the other regions of Indonesia affected by the tsunami; only seven people died in the population of 78,000. Risk awareness can be gained through personal experience of a

[1] Tsunami run-up is the maximum vertical height that the tsunami reaches on land above normal sea level at the time [43].

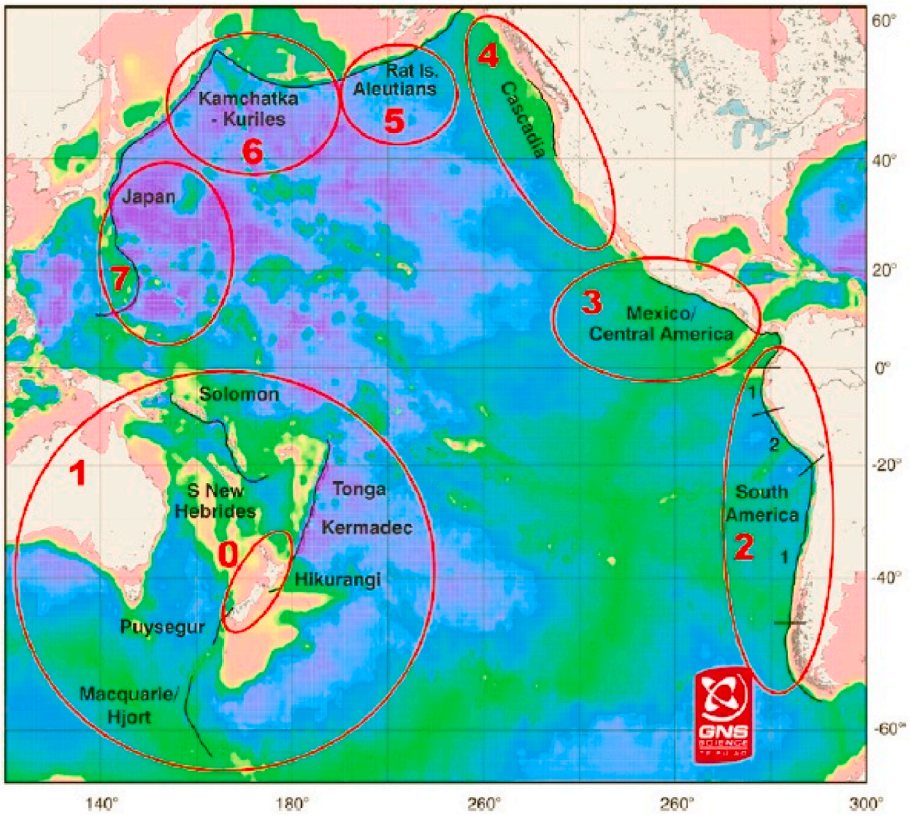

Fig. 1. Tsunami sources for New Zealand as presented in the "Tsunami hazard report" [9]. Zone 0 shows the potential source zone for local tsunami hitting New Zealand, Zone 1 is the regional source tsunami zone, and Zones 2–7 are distant tsunami source zones.

Fig. 2. Tsunami evacuation zone sign in Island Bay, Wellington [20].

disaster, such as in Indonesia [28], although experience can also lower risk perception and preparation behaviour [30–33] and is difficult to utilize to increase awareness and preparedness [34]. Interventions such as public education campaigns have been successful for outcomes including raising tsunami awareness [35–37], supporting the prioritisation of public awareness by NEMA [7,8].

Studies on tsunami awareness have proliferated worldwide since the 2004 Indian Ocean tsunami [3,28,38–40] [4,35,41]; and [37,42,43]. In New Zealand, a national coastal survey was undertaken in 2003, one year before this major event when public education on tsunami was inconsistent [2]. Not surprisingly, tsunami awareness among the public was very low. Most people were not aware they were living in a tsunami hazard zone, so the risk was not considered as a real threat and individual preparedness was virtually non-existent [44]. The low frequency of previous damaging events meant that perceptions of risk were based more on statements of probability which easily be misunderstood [45,46].

A constant but slow increase in tsunami awareness among the coastal populations of New Zealand has been observed since 2003 [4–6,37,47]. Studies show that New Zealanders now have a better understanding of tsunami hazard, but uncertainty remains about their understanding of what to do in case of a tsunami. Earthquakes as a natural warning of tsunami only began to be acknowledged by the public recently [4,37]. However, there are two issues with understanding an earthquake as a natural sign of tsunami. During interviews, residents and visitors in a coastal city did not immediately recognise the necessity of evacuating after an earthquake unless they were prompted to think about tsunami [4,6]. Second, even when respondents are conscious that a tsunami could follow within a very short time after a severe earthquake, they still tend to wait for an official warning before evacuating [4–6].

These findings are consistent with international literature which acknowledges that raising public awareness does not necessarily result in increases in individual preparedness [5,39,41,43,48,49]. Paton et al. [39] highlighted the importance of relationships with formal agencies and the sense of responsibility in evacuation decision-making [39]. Perceptions of formal agencies as not trustworthy are likely to have negative impacts on people's response to instructions given by those agencies. Social characteristics also play a role in evacuation decision-making, such as gender, age, ethnicity, and income, and the geographical context that may or may not facilitate the evacuation process [23,36].

Considering all of these factors, assessing people's reactions to a warning and evacuation order is a complex venture. Warning of a coming disaster can trigger many different reactions: disbelief [27], scepticism that leads people to seek additional information [5,36], or

even ignoring the warning and acting as if it did not happen [36,49]. However, even when a warning is accepted and acknowledged as an indicator of a real threat, evacuation is often not immediate and is preceded by numerous actions such as attempting to reunite with family members, packing life essentials or valuables, and consulting other community members and helping them if needed [4–6,36]. Some or all of these actions, if added together, can cause substantial delays in evacuating, meaning people fail to reach safety in time. This was a significant cause of casualties during the 2011 Great East Japan tsunami [35]. Another issue lies with transportation used when evacuating. Post-disaster studies globally show that most evacuees used their vehicle to leave the hazard zone, instead of evacuating on foot as recommended [5,35,36]. Indeed, this practice can cause traffic congestion in case of mass evacuation and increased the death rate during the Great East Japan tsunami [28,35].

In New Zealand, the most recent surveys revealed a discrepancy between people's perception of tsunami risk and the reality of a tsunami occurring [4,6,37]. Some misconceptions still remain despite improvements in tsunami awareness. First is the strong belief that an official warning would be given no matter how imminent the tsunami. Second is uncertainty about the ability of people to correctly interpret the natural warning signs of a tsunami. A survey following the 2013 Cook Strait earthquakes showed that respondents incorrectly interpreted the shaking, which was only moderate and did not last longer than a minute, as able to produce a tsunami [37]. Yet despite most respondents thinking that a tsunami could have been triggered, only 5% evacuated.

1.3. Study aims

This study had two main aims. First, by recruiting participants from the same ten locations as the 2003 National Coastal Survey, changes in tsunami risk awareness and perception between then and 2015 (the time of this survey) could be explored. Given the increase in efforts to educate about tsunami risk following the high-profile examples of the 2004 Indian Ocean and the 2011 Great East Japan tsunami, including the media coverage of these events, we expected awareness to be higher in 2015 compared to 2003. Second, this study reports levels of preparedness for tsunami as well as evacuation intentions, including what type of warnings people expect, what actions they would take before evacuating, and what mode of transport they would use to evacuate. These findings will provide valuable insight into how coastal communities in New Zealand can become more prepared for the event of a tsunami.

2. Method

This study used a questionnaire of 68 mostly-closed questions and sub-questions, with some open-ended when necessary [20]. Participants were asked about their knowledge of tsunami hazard, risk perception, knowledge of mitigation and self-responsibility, preparedness, and their evacuation intentions in the event of a tsunami warning both natural and formal. Although the questionnaire only focuses on tsunami risk (and earthquakes implicitly), its main purpose was not mentioned on the questionnaire form, to avoid influencing respondents' answers.

2.1. Topics in the questionnaire

Tsunami knowledge and experience: Questions in this section included concern about tsunami in relation to other natural hazards, knowledge of the most common causes of tsunami, and where they can be generated (i.e., geographical tsunami sources). Respondents were also asked if they had personally experienced tsunami or severe earthquakes and if they experienced loss or damage during any such events.

Risk perception: Respondents reported if their house was in a tsunami hazard zone, whether they believed that tsunami "are too destructive to bother preparing for", and whether they think that a serious tsunami could occur during the rest of their lifetime.

Knowledge of tsunami mitigation and self-responsibility: Respondents reported how they would expect to be warned about a tsunami within an hour and within 12 h and who they believed was responsible for ensuring communities are prepared for earthquake and tsunami (themselves, local council, regional council, or emergency services). Respondents were also asked if they felt prepared to deal with a tsunami and had undertaken preparation actions such as making a "getaway kit".

Evacuation intentions: Most of the questions used here were duplicated from past surveys in New Zealand [2,4,6] in order to obtain comparable results. When needed, questions were modified or rephrased to best match the present context. In this section, the three hypothetical tsunami scenarios for New Zealand were successively presented to the participants: a distant source tsunami (official warning of a tsunami coming in 9 h), a regional source tsunami (official warning of a tsunami coming in 1 h), and a local source tsunami (the earthquake as the warning). The local source scenario was presented first to avoid influencing respondents by obviously indicating to them that the earthquake is the warning. The same range of sub-questions was then duplicated for each scenario. This included questions about first reactions (e.g., what would you do?), if the participants were willing or not to evacuate, what they would do before evacuating, what kind of transport they would use to evacuate, how much time they think it would take, and where specifically they would go.

Demographic questions: Finally, respondents provided a range of demographic information including gender, year of birth, ethnicity, occupation, length of residency, education, income category, and family situation.

2.2. Sampling method and study area

The questionnaire was delivered to approximately 3000 households. The geographical area chosen as a focus was the East Coast of the North Island, from Wellington to Gisborne (Fig. 3). The tsunami hazard in this region is the highest in New Zealand as the proximity of the Hikurangi subduction zone means the area is prone to local source tsunami [9]. To allow for comparison, the same ten communities surveyed in the 2003 National Coastal Survey [2] were included in this study:

- Three communities in Wellington's urban area: Eastbourne, Seatoun, and Lyall Bay;
- Three rural communities on the Wairarapa coast: Castlepoint, Riversdale Beach, and Akitio;
- Three communities in Hawke's Bay: Haumoana, Te Awanga, and Westshore (in Napier's urban area); and
- One in the Gisborne area: Wainui.

Letters and questionnaires were hand-dropped directly in houses' mailboxes in June 2015. Three weeks later, the households who did not respond to the first request received another questionnaire, sent by way of standard post. However, participants' names were not recorded. The data from 874 valid responses were entered into SPSS Statistics Version 20 and most of the analyses were run with Le Sphinx 5.

3. Results

3.1. Tsunami risk perception

The first question asked respondents to select the two natural hazards (out of a list of eight hazards) that pose the most concern for their safety in their community. Tsunami was selected by the highest proportion of respondents (71%), followed by earthquakes (58%; see Fig. 4). In 2003, only 20% of participants selected tsunami as the hazard causing the most concern, with the top two hazards being coastal erosion (69%) and storms (49%). Possible explanations for this marked increase, along with the increased levels of communication about

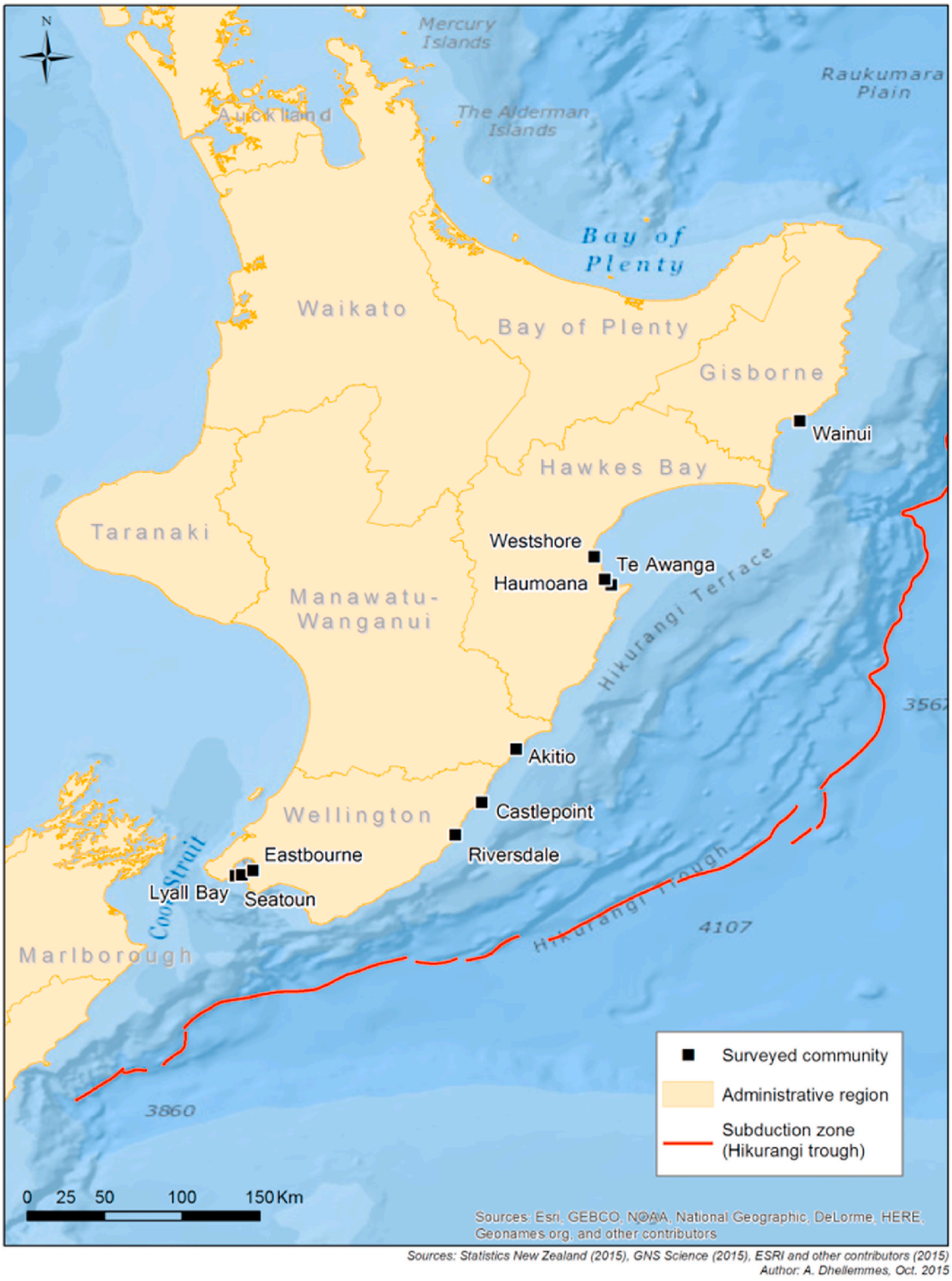

Fig. 3. - The ten selected communities along the East coast where questionnaire forms were delivered.

tsunami risk raised earlier, are presented in the discussion section.

The majority (88%) of respondents were aware that their house was located in a tsunami-prone area and 76% disagreed with the statement "Tsunami are too destructive to bother preparing for" (i.e., the majority of participants believe that they can prepare for tsunami). However, only 54% believed that a tsunami could occur within the rest of their lifetime.

3.2. Tsunami knowledge

Most of the respondents understood what a tsunami is and how it is generated. Most correctly identified the causes of a tsunami, from the most likely to the least likely: 1) local earthquake, 2) distant earthquake, 3) marine landslide, 4) volcanic eruption, and 5) meteor strike. When asked about geographical tsunami sources (in an open-ended question), the most cited sources were correct: South America (mentioned by 28% of the respondents), the Cook Strait (15%), and the East Coast of the North Island (12%). The majority were able to cite at least one exact tsunami source (57%), but less than 5% were able to cite three or more exact sources. Almost 80% thought they would have no more than 30 min to move to safety from the tsunami hazard zone after a strong and/or long earthquake. In 2003, 50% thought they would have within 30

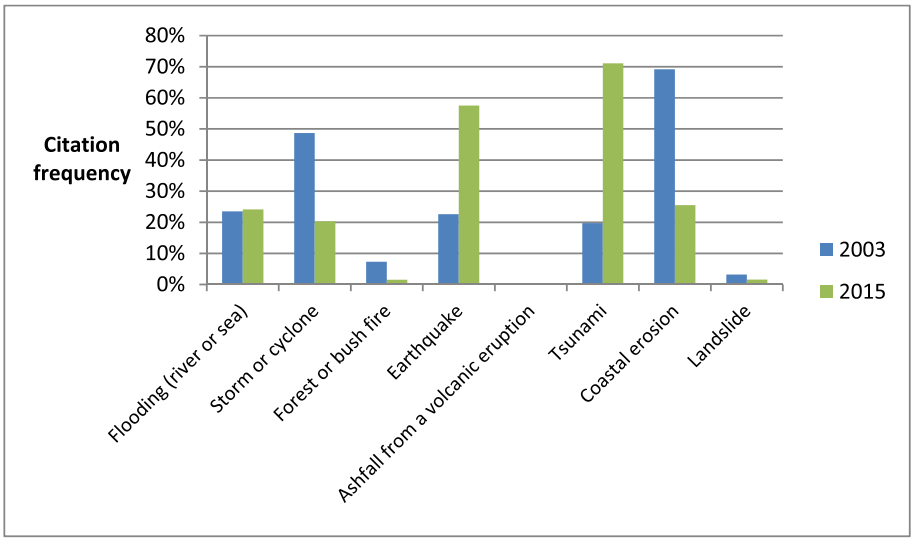

Fig. 4. Answers to the question "What two possible natural hazards cause a concern for your safety or create a risk to your livelihood in this community?" in 2003 and 2015.

min or less to move to safety after a strong felt earthquake [2]. Moreover, in 2003, 38% of the respondents did not know what to answer to this question, while in 2015, they were more confident, with this percentage going down to 11% (see Fig. 5).

3.3. Knowledge of tsunami mitigation and self-responsibility

Eighty-four percent of the respondents had previously received information about how to prepare for tsunami from various official agencies. When asked to rank the responsibility of different official agencies (local council, regional council, emergency services) as well as their personal responsibility for earthquake and tsunami preparedness, most respondents considered themselves as primarily responsible for ensuring their own safety in case of a tsunami (63%). Only 46% of respondents assumed that they are prepared enough to deal with a tsunami. However, almost 60% reported having a getaway kit ready to go at their home and 87% knew where they would evacuate to in case of a tsunami warning. It is important to note that we did not assess whether intended evacuation places are appropriate (i.e., outside of the tsunami hazard zone).

Respondents were also asked how they expected to be warned that a tsunami is coming in 12 h and for a tsunami coming in 1 h (see Fig. 6). The results showed no notable difference between the answers for the two scenarios. Half of participants (51.3%) thought that feeling an earthquake would warn them of a tsunami coming in 12 h, which is unrealistic since the earthquake which triggers a distant source tsunami would not be felt in New Zealand. The most selected option was "Radio and TV" for both scenarios. However, sirens were also highly expected (close to 70% for both cases) although there would be no time for a warning siren for a local tsunami. On the other hand, the "text message" and "smartphone application" options were not considered as particularly likely warnings (between 10 and 20% expected warnings from these sources); NEMA have since trialled nationwide Emergency Mobile Alerts in 2018 and 2019,[2] and used this system in 2020 to communicate changes in the New Zealand Covid-19 Alert Levels, so it is likely these perceptions have changed.

[2] https://getready.govt.nz/prepared/stay-informed/emergency-mobile-alert/nationwide-tests/.

3.4. Evacuation intentions

In this section, three hypothetical scenarios were successively presented to the participants. The first scenario described a local earthquake but made no mention of a triggered tsunami to see if respondents would independently relate a strong and/or long earthquake to a possible tsunami. After presenting the scenario, respondents were asked if they would evacuate their home (see Fig. 7). Most (70%) said that they would evacuate; of those who said they would not evacuate, they indicated they would wait for an official warning telling them to leave (9%) or wait and assess the situation first (7%).

The same question was repeated for the distant (Scenario 2) and regional (Scenario 3) tsunami scenarios. For Scenario 2, most people who said they would not evacuate immediately still planned to evacuate eventually (10%). Only a small proportion of the sample (6%) were reluctant to evacuate, giving answers such as: "it may reduce in severity or never happen" (4%) or "I don't trust the warning" (1.5%). The proportion of those who said they would not evacuate in Scenario 3 was lower than for the two other scenarios (4%) with most of these respondents stating that they "would wait for more information".

The following questions aimed at a deeper investigation of the evacuation process itself: what would people do prior to evacuating, how long is it going to take, and how would they travel to safety? The survey revealed that most people plan to carry out several actions before evacuating in every scenario (see Table 1). The most common actions were: getting life essentials, seeking further information, and gathering family. Results for Scenario 1 (earthquake) and Scenario 3 (regional tsunami) are quite similar, whereas the proportions of participants reporting that they would take each of the actions were higher for the distant source tsunami (Scenario 2).

People were then asked how much time they would take before they actually started evacuating. For Scenarios 1 and 3 (local and regional source), almost all respondents expected they would evacuate within 30 min and most expected they could evacuate within 10 min (see Table 2). Again, the pattern looks different for Scenario 2 (distant source); most of the respondents believed they would start to evacuate between 30 min and 3 h after the warning.

Most respondents (between 65% and 79%) intended to use their vehicles to leave the hazard zone in all scenarios (Table 3), especially for Scenario 2 (distant tsunami). However, for the local scenario (Scenario 1) the percentage of people who intended to evacuate on foot and those who intended to evacuate by car is similar (Table 4). Evacuating by

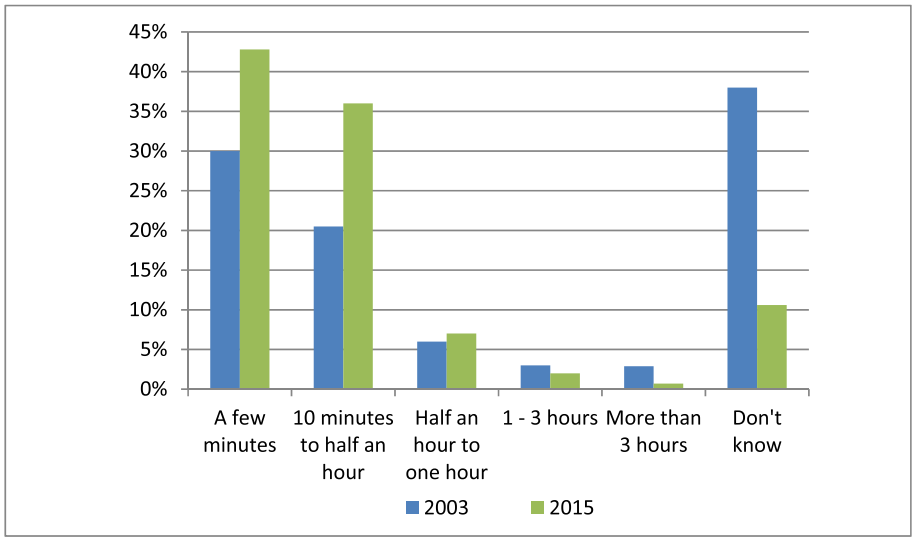

Fig. 5. Answers to the question "If you feel a strong earthquake while at the beach, how much time will you have to move to safety from any approaching tsunami it may cause?" in 2003 and 2015.

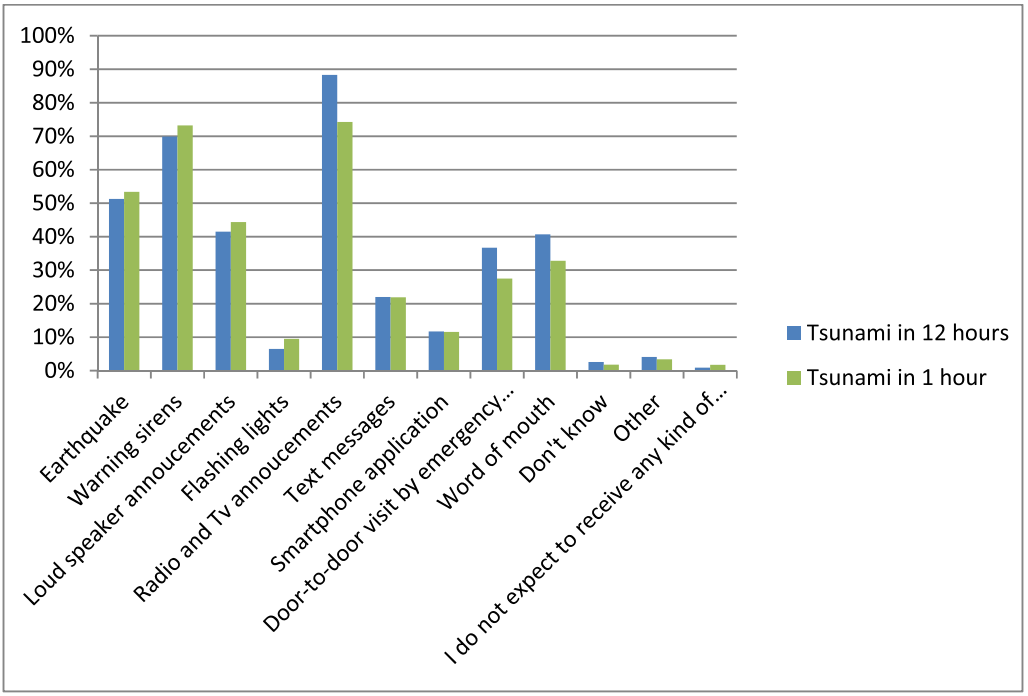

Fig. 6. How the respondents expect to be warned that a tsunami is coming, within 12 h and within an hour.

bicycle is not widely considered (around 10% for each scenario) and other proposed options (public transport or flight) are barely considered (see Table 3).

3.5. Geographical differences observed

Respondents' community of residence was examined for its influence on responses. Three groups of communities were created,[3] based on the assumption that geographically closer communities are more similar than geographically distant ones:

- Communities in the Greater Wellington area (Eastbourne, Lyall Bay, Seatoun);
- Communities of Hawke's Bay (Westshore, Haumoana, Te Awanga); and
- Community of Wainui to represent the Gisborne region.

Tsunami risk perceptions were slightly higher in Wainui (Gisborne) where 80% of the respondents rated the hazard as very concerning compared to the average of 71% across the whole sample. More respondents from Hawke's Bay communities declared they did not receive any information about preparing for tsunami (20%) than in the other communities (14% in greater Wellington; 12% for Wainui-Gisborne);

[3] Rural communities of the Wairarapa coast were excluded from this analysis since the number of returned questionnaires was not sufficient for cross-tabulations.

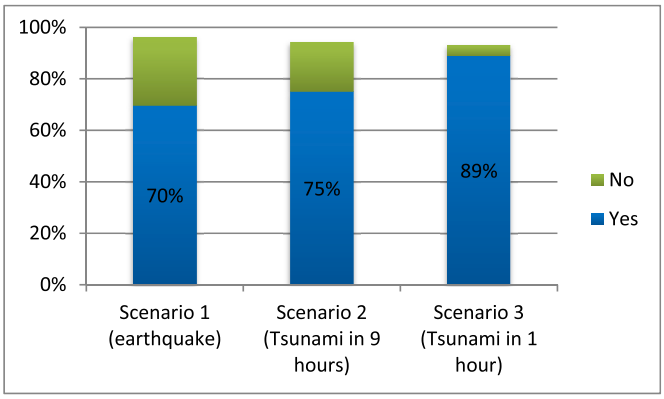

Fig. 7. Willingness to evacuate or not according to three different tsunami scenarios (1: local (earthquake); 2: distant (9 h); 3: regional (1 h)).

Table 1
Actions that respondents are willing to do before evacuating, according to each scenario.

	Scenario 1 (local source)	Scenario 2 (distant source)	Scenario 3 (regional source)
Nothing (evacuate immediately)	6%	1%	7%
Gather family	56%	65%	60%
Get life essentials	77%	89%	83%
Collect valuables	26%	67%	38%
Call family or friends	28%	70%	37%
Assist others in evacuation	56%	77%	53%
Seek further information	60%	88%	56%

Table 2
Time respondents think it would take before they start evacuating.

	Scenario 1 (local source)	Scenario 2 (distant source)	Scenario 3 (regional source)
One minute or less	7%	<1%	3%
1–10 min	55%	14%	45%
10–30 min	26%	28%	38%
30 min–1 h	7%	21%	7%
1–3 h	1%	26%	1%
Longer than 3 h	1%	6%	0%

Table 3
Transportation respondents think they would use to evacuate.

	Scenario 1 (local source)	Scenario 2 (distant source)	Scenario 3 (regional source)
Car	65%	79%	67%
Foot	64%	37%	52%
Public transport	1%	3%	2%
Flight	<1%	1%	<1%
Bicycle or similar	13%	10%	10%

Note. Participants could report multiple intended evacuation methods.

respondents who declared they had not received any information tended to give longer time frames for evacuation after a large earthquake. There were no differences between communities in terms of mitigation knowledge (e.g., knowledge of a community evacuation map, warning method for a distant source tsunami) or sense of responsibility.

Table 4
Cross tabulation between communities and expected transportation mode use for each scenario.

	Scenario 1 (local)		Scenario 2 (distant)		Scenario 3 (regional)	
	Foot	Car	Foot	Car	Foot	Car
Wellington communities	88.6%	40.1%	45.4%	67%	74.1%	47%
Hawke's Bay communities	38.6%	89.6%	26.9%	91.5%	28.5%	85.8%
Wainui-Gisborne	64%	64%	41.9%	78.8%	54.7%	68.6%

Finally, differences were observed in evacuation intentions in terms of transportation to leave the tsunami hazard area. In Wellington, people were statistically more likely to evacuate by foot (between 75 and 80%, depending on the scenario) rather than by car (between 40 and 50%) for local and regional scenarios. Residents of Hawke's Bay stated they would evacuate mostly by car for every scenario (between 85 and 90%). The difference between these two options is smaller in the Gisborne community, but the majority were still likely to use their vehicle to evacuate (between 65 and 75%).

3.6. Other influencing factors

There were differences between age groups on information received: the oldest age group (65+) was better informed; 50% of the youngest age group (18–30) believed it was their responsibility first compared to the average of 63%; the youngest respondents were less able to cite valid tsunami sources and tended to cite longer time frames to get to safety after a strong earthquake; and the youngest felt less prepared, with only 15% declaring themselves to be prepared for tsunami risk compared to 53% for the oldest age group. However, more elderly participants refused to evacuate (for all the three scenarios) than younger respondents.

While about half of respondents (56%) stated they had lived in their community for at least ten years, preparedness tended to be higher among respondents who had been resident for a shorter time, especially those who settled between six and ten years ago. More newly settled respondents were also more aware of their exposure to tsunami risk with 95% of the people who arrived between six and ten years ago knowing their house is in tsunami hazard zone compared to 88% on average. These respondents also had better hazard knowledge and were more likely to intend to evacuate. Families with children tended to have received more information, were more aware of their risk exposure (93% are aware compared to 88% on average), and were more willing to evacuate. However, they would undertake more actions before evacuating (gathering family and essentials), therefore taking more time than other households.

University graduates were highly conscious of being exposed (92% knew they were in a tsunami-prone area) and tended to have a high tsunami knowledge. For instance, they were more able to cite precise tsunami sources, such as the Kermadec Trench or Pacific "Ring of Fire", while a higher proportion of less educated people cited wrong or vague sources (e.g., "Asia", "Antarctica"). However, this difference between education levels in knowledge did not appear to extend to evacuation intentions.

4. Discussion

4.1. Changes in tsunami awareness between 2003 and 2015

Perceptions of tsunami risk increased dramatically between 2003 and 2015, with 70% compared to 20% of respondents now identifying tsunami as one of the most concerning natural hazards faced by their community. This heightened awareness of tsunami risk is consistent

with other recent, similar surveys [4,6]. Experience of a hazard can influence the salience of both that hazard and others, thereby affecting perceptions of vulnerability [50]. It is possible that the Canterbury earthquake sequence in 2010/2011, which did not directly impact this area but had widely publicised, catastrophic impacts, led to an increase in concern about earthquakes and the associated hazard of tsunami. This increase in concern in these two hazards would likely have contributed to the decrease in concern about the previously-highly salient hazards of storms and coastal erosion as people tend to focus on a limited number of hazards [50].

Respondents' answers for tsunami knowledge have changed over time; in 2003, only 50% thought they would have within 30 min or less to move to safety after a strong felt earthquake [2] while in 2015, 80% selected this timeframe. Moreover, in 2003, 38% of the respondents did not know what to answer to this question, while in 2015, residents were more confident in their knowledge with only 11% indicating they were unsure how to answer the question.

The 2004 Indian Ocean and the 2011 Great East Japan tsunami events, which occurred between the 2003 and 2015 surveys, likely impacted public awareness and knowledge of tsunami through extensive media coverage [42], including key factors such as how quickly local source tsunami can reach shore, as well as the already-mentioned increase in communication from New Zealand agencies. In 2003, half of respondents (55%) declared they never received any information about how to get prepared for a tsunami; in 2015, this was 15%.

4.2. Perceptions across tsunami scenario

However, the different levels of tsunami risk might not be well understood yet. New Zealand faces the challenge of getting prepared for three different tsunami scenarios (distant, regional, and local source tsunami), including ensuring people recognise these three different types of threats so they can respond properly to each. However, only about half of respondents could correctly name one tsunami source; only 1.5% could accurately name a local, regional, and distant source. Encouragingly, the majority of respondents did (correctly) indicate that they would have less than 10 min to begin evacuation in the event of a local source tsunami, although many intended carrying out other actions before evacuating, and then suggested they would evacuate by car.

Intentions to undertake other actions before evacuating and then to evacuate by car were higher in the regional and distant source scenarios. This is understandable and likely not overly problematic in the event of a distant source tsunami where several hours warning should be possible. Such behaviour is concerning for a regional source tsunami, especially given the high expectance of official warnings through sirens or radio/TV announcements which may not be possible in the time frame. Recent media campaigns in NZ have focused on teaching natural warnings (long or strong shaking) and emphasized that tsunami could arrive before official warnings are able to be given; the findings of this study support the continuation of such education efforts.

Gathering family, even if it seems essential, is not necessary if family members know where to meet in case of emergency. Seeking further information, calling family or friends, or collecting valuables would unnecessarily delay the evacuation. The only "appropriate" actions for Scenarios 1 and 3 would be to grab an emergency kit (if already assembled) and to help people that require assistance, such as disabled people, young children, or the elderly. This type of response was also noted in previous similar studies already discussed, either based on hypothetical tsunami scenarios [4,6], or after real tsunami [5,36]. Whether people persist with the idea of leaving by car since they assume it is the easiest and fastest way to get to safety or because they have not received effective advice on this issue, this should be a focus of ongoing education. As shown by the example of Japan, many people died during the tsunami in 2011 because they decided to use their car to evacuate instead of walking, creating traffic congestion (especially on roads that may be damaged in the case of a local earthquake) which prevented or delayed people reaching safety [35].

On the other hand, some improvements in evacuation intentions since previous surveys can be seen. First is the large majority of respondents willing to evacuate for each scenario (Fig. 7). In 2013 in Napier, 57% of people who were interviewed stated they would evacuate their home after a large earthquake [4], while this percentage was close to 70% in 2015. The Napier survey was undertaken in different conditions (face-to-face interviews on the street instead of mailed questionnaires) which could have influenced responses, although biases such as social desirability and researcher expectancy would predict that face-to-face methods would result in higher evacuation intentions.

However, despite best intentions, actual evacuation for tsunami threat in New Zealand remains mixed. For example, following the 2016 Kaikōura earthquake, which generated a local tsunami, only 11% evacuated from Petone and Eastbourne in the Wellington region immediately due to feeling the long/strong earthquake [51]. While 69% did eventually evacuate because of a potential tsunami (which is a similar percentage to people's anticipated responses from the 2015 survey), 33% did not evacuate within the 10-min timeframe. That many did not evacuate fast enough for a local source tsunami highlights that despite best intentions, some people will be delayed during an actual evacuation. As explored in the 2015 survey, reasons for this delay might be waiting for an official warning, gathering life essentials, seeking further information, and gathering family, or might be related to the mode of transport people choose to take when evacuting (e.g. considering taking a car, rather than walking or biking).

4.3. Influencing factors

Dash and Gladwin [23] showed that some demographic factors can influence evacuation decisions, particularly age, presence of children or elderly in the household, gender, disability, ethnicity, and income. These factors can either motivate or constrain evacuation, depending on the context [23]. In this study, age appears to be associated with tsunami awareness and preparedness, especially when comparing the youngest (18–30) to the oldest age group (65+), with older age groups demonstrating better tsunami awareness and knowledge, receiving more information about how to prepare, and feeling more prepared than younger age groups. However, older respondents, and similarly those who have lived the longest in their community, are less likely to evacuate their home in case of a tsunami, emphasizing that strong risk awareness does not necessarily result in appropriate protective behaviour. Families with children are more likely to evacuate later than other types of households as they intend to undertake more actions before evacuating, likely because taking care of their children is their priority. Finally, more highly educated respondents have better knowledge about tsunami hazard. However, this does not seem to influence their evacuation intentions.

Community of residence has less influence on people's answers than expected. The only notable difference is that Hawke's Bay residents are apparently less informed than residents from other communities in terms of information previously received (except for Wairarapa communities) and that the highest intended use of cars to evacuate was found in the Hawke's Bay communities. This difference can be at least partially by explained geography; coastal communities of Hawke's Bay lie on flat land, while Wellington's landscape is hillier, which means that locations safe from tsunami would be closer to reach in Wellington than in Hawke's Bay. It is also possible that the higher reliance on personal vehicles for commuting in the Hawke's Bay compared to Wellington, where people are more likely to live and work within a distance short enough to walk or use public transport, results in higher vehicle ownership and a predisposition to use this type of transport.

4.4. Learning from the 2015 survey

Tsunami awareness in New Zealand has increased since 2003.

However, particularly when looking at evacuation intentions, preparedness is not yet optimal. This finding confirms that raising public awareness does not always increase individual preparedness. While most respondents knew that they live in a tsunami hazard zone and believe that it is possible to prepare (88% and 76%, respectively), only about half believed that a damaging tsunami could occur in their lifetime. The time frame within which people anticipate the occurrence of a tsunami is a "moderator" for tsunami preparedness [43]. Similarly, the belief that tsunami affecting New Zealand are all limited in size and damage only harbour infrastructure, such as the 1947 Gisborne tsunami and other previous events in recent memory, is likely to play an important role [31]. These findings demonstrate the importance of educating about the impacts and likelihood of natural hazard events such as tsunami to help translate awareness into preparation.

Tsunami awareness in Japan is high because major tsunami have been relatively frequent there. In some coastal communities which had been previously affected by several damaging tsunami, up to 96% of people who were living in the inundated zone survived the 2011 Great East Japan tsunami because they knew to evacuate early enough [35]. However, other communities further south along the coast had previously experienced many earthquakes but with few resulting in tsunami. As a result, risk education focussed on actions related to earthquake but less on tsunami. This led to lower evacuation rates and more fatalities in 2011 [35]. While traumatic experience is likely to increase understanding of the need for tsunami preparedness, the existing preparedness evident in New Zealand communities despite the lack of major events suggests that experience in this sense can be motivating but is not essential.

4.5. Recommendations

Considering the above, several recommendations can be made to improve New Zealand's tsunami preparedness. First, information about tsunami causes and sources could be more specific, with a particular aim to educate on the types of warnings which might be given for different scenarios. For example, when asked "what is your reason for not evacuating after feeling a large earthquake?" most said they would wait for an official, public warning, demonstrating that tsunami knowledge can still be strengthened in terms of when warnings would be issued and how to interpret the natural warnings of an earthquake. Specificity around earthquake sources would also help to explain in which situations people should, or should not, use their car to evacuate. For example, it is acceptable to drive to evacuate from a distant source tsunami when there should be ample warning time to avoid traffic congestion and when the originating earthquake has not damaged the roads. In the case of a regional source tsunami or local scenario, driving should be discouraged when not necessary (exceptions include assisting elderly or disabled people) because of the large numbers of people needing to evacuate in a short time along a limited number of routes and the potential for roads to be damaged during the preceding earthquake. Official advice on how to evacuate generally agrees at a high level but varies considerably in phrasing. For example, WREMO's website says "Immediately evacuate out of tsunami zones on foot or bicycle" [52] while NEMA (getthru.govt.nz, 2016) says "drive only if essential", and Hawke's Bay Civil Defence and Emergency Management website specifies "walking […] [53] might be better than driving, as roads may be damaged in the earthquake" (HBCDEM, 2016). It seems important to align the advice and provide common justification for walking rather than driving.

Community-based initiatives to increase preparedness should be encouraged [39], such as the tsunami blue lines and evacuation routes in Island Bay, Wellington, which were discussed with community members. As a result, residents from this community are better prepared because they know where to evacuate [6,37,54]. This work has implications for other areas, including other parts of New Zealand, which are at risk of tsunami.

Tsunami drills constitute a useful educational community activity and are included in yearly emergency decision-making simulations in Japan [35]. Some Japanese prefectures or communities also hold their own tsunami evacuation exercises. The benefit of this strategy is that evacuation goes from a vague concept to a reality. It helps people to process the information given by authorities by showing what an evacuation truly involves and promotes good responses by people who will be able to replicate what they learned should a tsunami occur. These evacuation drills should to be organised on a regular basis, to prevent people from forgetting and ignoring the risk in the future, as it has been demonstrated that if reminders are infrequent, it has a negative effect on preparedness [5].

Past tsunami drills in New Zealand have seen low participation rates, such as the "Get ready Get Thru The Vines" [55] exercise held in Hawke's Bay in 2010 [56]. However, conclusions drawn from this initiative were promising, since it was described as "one of the best forms of education" and that members of the public enjoyed the experience. Since then, other tsunami evacuation exercises have been successfully run across the country since then in places such as Orewa, where residents collaborated with researchers to practice tsunami evacuation hīkoi (walks) with schools and the wider community [45,46]. As of 2016, less than a third of schools in Wellington, New Zealand, included tsunami evacuation in their earthquake drills, and less than half discussed tsunami [57]. Research in the US demonstrates the importance of properly including tsunami evacuation in earthquake drills; in a study of two school districts in Washington State, over a quarter of the students did not realise that an action they practised (vertical evacuation) was for the purpose of tsunami [58]. These studies argue for including tsunami practice in earthquake drills, particularly in schools, but demonstrate the importance of communicating the purpose and benefit of particular actions. Tsunami hīkoi are also now encouraged by NEMA as part of the annual ShakeOut earthquake drill [59]. Participation in the ShakeOut drill has been found to enhance knowledge of and attitudes towards earthquake preparedness, and promote people taking correct actions in a drill [60]. Undertaking tsunami hīkoi as part of the ShakeOut will extend these benefits to tsunami evacuation, with the benefit of potentially saving lives in a future event.

5. Limitations

A sample of 874 responses from ten different communities was sufficient to assess East Coast New Zealanders' level of awareness and preparedness of tsunami risk. However, the study has some limitations that ought to be noted:

- This survey used self-report methods and is therefore open to response biases such as social desirability and researcher expectancy;
- The survey method of posting the questionnaire to the households instead of doing face-to-face interviews eliminates the "pressure effect" posed by direct interviews. Consequently, answers of this survey are potentially well thought-out rather than spontaneous;
- It is possible that some participants interpreted questions differently. For example, the fatalism item "Tsunami are too destructive to bother preparing for" is potentially open to different interpretations. Although this item has been used widely as part of the full scale which tends to demonstrate good internal reliability, future work could consider adding a question assessing how destructive people perceive tsunami to be;
- Some communities provided a limited number of responses, especially the rural communities on the Wairarapa coast (Akitio and Riversdale). Consequently, these responses might not be representative for these communities; and
- The lack of previous experience means that respondents are reporting what they imagine their reaction would be. The gap between behavioural intentions and actual behaviour is often unavoidable but worth noting.

6. Conclusion

This study aimed to assess tsunami awareness and preparedness in New Zealand in 2015, drawing comparisons to the last national survey undertaken in 2003 [2]. As well as catastrophic tsunami events that struck some parts of the world in the recent past (2004 Indian Ocean tsunami; 2011 Great East Japan tsunami), notable efforts to raise tsunami awareness were initiated in New Zealand. Improving awareness was defined as one of the four key areas for getting nationally prepared by the national Tsunami Working Group of NEMA. As a result of both the recent large-scale tsunami that have devastated other areas of the world and public education, tsunami awareness in New Zealand has markedly increased since 2003.

Most of the coastal residents who participated in this survey, regardless of their community, know that their household is exposed to a potential tsunami and consider it as one of the most concerning natural hazards. However, based on responses to hypothetical tsunami scenarios, many respondents are not fully prepared to deal with such risks. Many of the key messages published by NEMA and other agencies are still not fully understood, including the differences between local, regional, and distant tsunami sources, what warnings could be expected for each, and the best ways to evacuate. Developing an effective tsunami warning and public alerting system is also one of the key areas for advancement [61]. The development of tsunami warning systems, including recent trials of emergency mobile alerts, will likely help reduce the confusion that remains around tsunami warnings if it is paired with effective public communication about the role of such alerts, and the actions people need to take for tsunami from different sources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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