Natural Hazards Commission
Toka Tū Ake

Exploring influences on building earthquake resilience in lower seismic hazard zones

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Executive Summary

While Tāmaki Makaurau Auckland has an objectively lower seismic hazard than other parts of Aotearoa New Zealand, the likelihood and potential intensity of earthquake shaking is still relatively high on a global scale. However, the lower hazard compared to other parts of the motu mean that fewer steps have been taken to reduce or mitigate earthquake impacts, such as the area having a longer timeframe to strengthen earthquake-prone buildings. This may lead to the *risk* being inflated; that is, if the hazard is lower and therefore steps are not taken to address it, then the risk can be magnified. For example, the extended timeframe for strengthening earthquake prone buildings in Auckland compared to other parts of the country may mean that a relatively small shake could cause more damage than a similar-sized event in a different city with a shorter timeframe, such as Wellington.

Therefore, it is important to understand how people think about and act on their seismic risk in these lower hazard areas such as Auckland. In particular, previous research suggests that these perceptions may be influenced by comparisons to other parts of the country as well as comparisons to other hazards within the region. These potential mechanisms will be important to understand in order to maximise the impact of communication campaigns to encourage earthquake preparation actions.

This research involved two stages, using a survey and interviews to collect different types of data (quantitative and qualitative) which could complement each other to better explore the existence and influence of the mechanisms described above. Across our samples, we found moderate levels of preparation actions with clear room for improvement, as well as mixed views on the preparedness of official agencies to respond. Further, we found mixed results for the prominence of earthquakes as a *perceived* hazard in Auckland as well as conflicting influences of comparisons to other places. These findings suggest that the differences between groups, areas, and even individuals within Auckland may be too large to consider the region as a homogenous whole. However, we did find consistent evidence that how people thought about some of their hazards (in particular earthquakes and volcanoes) was affected by their recent experience of severe weather. Further, we found that while many participants said they got a variety of types of information about earthquakes from a range of sources, there are clear ways to improve communication and public education.

We make several recommendations, including future work exploring these questions at a more specific level rather than across the Auckland region. We also suggest tailoring post-event communication campaigns to focus on the impacts of the event which may be common across a range of hazards and outreach from official agencies explaining steps which have been taken to improve response preparedness. Finally, we recommend reviews of existing public education campaigns to identify whether any of the improvements suggested by our participants could be put into action.

The questions addressed in this research are important but complex; while our findings have clarified some of the picture, more evidence is needed to fully understand how people think about and act on their earthquake risk in different hazard contexts. Future work could explore the role of spatial and hazard comparisons in other low(er) seismic hazard zones within Aotearoa, as well as considering specific sociodemographic and geographic subgroups within the Auckland region.

Technical Abstract

This research explored two key potential mechanisms affecting how residents of Tāmaki Makaurau Auckland perceive and act on their seismic hazard: spatial comparisons and hazard comparisons. Previous research has shown that how people think about their own seismic risk can be influenced by comparisons to other parts of the country with an objectively higher hazard profile, typically with a suppressive effect on behaviour. Similarly, people may perceive less risk from earthquakes and be less inclined to take preparation actions if there are other, more salient hazards in their environment, either through cues (e.g., the prominence of volcanic cones in the region's landscape) or through recent experience (e.g., the severe weather events of early 2023). We also explored experiences and perceptions of current information sources and types, as well as ideas for improvement.

The first phase involved an online quantitative survey (*N* = 638), the findings of which contributed to the development of semi-structured interviews (*N* = 8). The survey was disseminated via social media posts targeted to the Auckland Region, with data analysed both descriptively and inferentially. Interviewees were recruited from the survey participants. Each interview was conducted online and lasted between 30 and 45 minutes. Across the two data types, we found some conflicting and some consistent evidence to answer our research questions. Survey respondents rated earthquakes highest for frequency of thought, likelihood, and severity of impact, while volcanoes were ranked the lowest across all three factors; however, volcanoes were the most (equal) cited hazard by our interview participants and earthquakes the least. We found little evidence of spatial comparisons in the survey. This was potentially explained by our interview analysis showing that spatial comparisons can have either a negative or a positive influence on earthquake risk perception depending on the individual. The role of relative hazard may therefore be individual and context dependent.

The 2023 severe weather events allowed us to employ a natural experiment design in our survey to test the role of hazard comparisons; those participants who were negatively affected by the weather events rated earthquakes significantly lower across all three factors (frequency of thought, likelihood, and impact severity) compared to those who were not affected. However, this weather experience did not appear to have a suppressive effect on risk perceptions of other hazards; future work should explore why earthquake perceptions were affected but others were not. Several of our interview participants also noted the impact that these severe weather events had had on their general risk perception and preparation, as well as temporarily suppressing their concern about other hazards such as volcanic eruption.

Finally, our survey participants reported receiving information about earthquakes from a large range of government, science, and community sources; however, our interview participants struggled to recall who had provided the information they had seen. Across the two research phases, there was clear desire for information to be communicated in more ways than is currently being done, including through channels such as advertising on public transport, face-to-face community events, and signage in high-risk areas (such as at the coast for tsunami).

Across this research project, we have identified several potential mechanisms affecting how people in Tāmaki Makaurau Auckland perceive their seismic risk; however, in several instances these mechanisms had conflicting or inconsistent impacts, such that further work is needed to better understand precisely what influences people in relatively lower seismic hazard areas to take steps to build their earthquake resilience.

Keywords

Earthquake, multi-hazard, risk perception, communication, preparation, social science, empowering people.

Introduction

Research Context and Problem

Previous research has identified relatively low natural hazard risk perception and preparation in Tāmaki Makaurau Auckland (Johnston et al., 2017b). While this area is typically classed as low or lower seismic risk, this is in comparison to other areas of Aotearoa New Zealand (NZ) which is a highly-seismically active country. These comparisons can lead to low preparation (particularly mitigation actions such as strengthening homes) and therefore poorer outcomes in areas which are at objectively lower, but still significant, seismic risk (McClure et al., 2011; 2015a). National and city level surveys show an increase in preparation following a significant event (e.g., Vinnell et al., 2019); however, at this point damage and harm has already occurred. It is therefore critical to explore and aim to reduce barriers to earthquake preparation based on pre-event factors such as risk perception. Given the level of seismicity across the motu, such work will have benefits for other parts of NZ with lower seismic hazard, such as Te Tai Tokerau Northland and Ōtepoti Dunedin (Johnston et al., 2017a).

The context in which people perceive their risk can have meaningful impacts on preparation behaviour such as earthquake strengthening (Vinnell et al., 2017). We therefore need to identify barriers to earthquake preparation in areas of relatively lower seismic risk so that we can inform existing practice, public education, and policy to reduce the amount of damage and harm experienced when an earthquake does occur. Biases including unrealistic optimism, where people understand that earthquakes will occur and cause negative impacts but do not believe that they will be personally affected, inhibit preparation behaviour such as retrofitting buildings to better withstand shaking (Becker et al., 2015). Although some previous research demonstrates the role of comparative risk judgments throughout NZ (e.g., Johnston et al., 1999), further research is needed to understand how exactly these judgments work to inhibit behaviour as well as how end-users can communicate, educate, and make policy decisions to reduce these barriers.

In this research, we conceptualise “hazard” as a process or phenomenon which has the *potential* to impact people, property, or the environment. “Risk” is the threat posed by a hazard, as a function of the likelihood of that process occurring and the impacts it would have should it occur, considering factors such as who and what is exposed (e.g., buildings in proximity to a faultline) and how vulnerable those people and assets are (e.g., ability of those buildings to withstand earthquake shaking). The differentiation between hazard and risk is particularly important; Auckland has an objectively lower seismic *hazard* than other parts of the country (e.g., earthquake shaking is expected to be less strong) and this cannot be changed, given it is determined by geological forces. However, Auckland’s *risk* from earthquakes depends on factors which can be controlled, such as where and how buildings are constructed.

Research Objectives and Answers

There are three main objectives of this research, all aimed towards addressing the problem above.

1. Spatial comparisons: Firstly, there is the question of whether and how (i.e., beneficial or detrimental) Aucklanders’ perception of their seismic *risk* is influenced by comparisons of their *hazard* to that in other parts of the country.
2. Hazard comparisons: Secondly, seismic risk perceptions in Auckland, and subsequent behaviour, may be influenced by comparisons to *other* hazards, including ones which are more salient (e.g., volcanic eruptions) and more recently experienced (e.g., severe weather such as extreme rainfall and flooding).

3. Risk communication: Finally, this research also explores current opinions of, and ideas for improvements to, existing communication efforts of both risk information and risk reduction options.

Spatial comparisons

One major concern in terms of earthquake risk perception and preparedness is that those in low(er) seismic hazard zones may displace their risk onto areas of higher hazard. That is, because earthquakes are objectively more likely elsewhere in the country, people in Auckland may assume that earthquakes will occur in those places *rather than* in Auckland. For example, many people (>60%) in one survey reported thinking *before* the Canterbury Earthquake Sequence that an earthquake near Christchurch was unlikely because they thought it would happen elsewhere (McClure et al., 2015a).

We found mixed evidence for this proposed effect. In the survey, there were no clear relationships between perceptions of the likelihood of earthquakes in other regions of NZ and perceptions of risk in Auckland. However, the interviews suggest that this may be because of conflicting effects; some participants reported feeling less concerned about earthquakes in Auckland because they think they are more likely somewhere else in NZ, while some participants reported feeling *more* concerned about earthquakes in Auckland after seeing the severity of recent events in other parts of the country. Therefore, comparisons to higher seismic hazard zones are important to consider in terms of risk perception in lower seismic hazard zones, but they are likely not as straightforward and unidirectional as hypothesised.

Hazard comparisons

A second major potential influence on how people in Auckland perceive their earthquake risk is the role of other hazards (Ardaya et al., 2017; Boholm, 1998). Thinking about one natural hazard event can be psychologically challenging given the threat they may pose, leading to the hypothesis that it is difficult for people to perceive multiple risks at the same time. Instead, they may cognitively downplay those which are less salient. For example, perceptions of earthquake risk stayed the same in one town not impacted by the 1995 Ruapehu eruption but *decreased* in another town which experienced ashfall (Johnston et al., 1999).

This effect emerged clearly in analysis of the survey data. Those participants who had recently been impacted by severe weather events thought about earthquakes less, saw earthquakes as less likely, and thought the consequences of an earthquake would be less severe than those participants who had not recently been impacted. Similarly, when asked to name which natural hazards they think will be most impactful on them, earthquakes were mentioned by two interview participants (of eight), while volcanoes and rain/flooding/weather were mentioned by seven.

Risk communication

The final objective of this research was to explore current engagement with and perceptions of existing risk communication efforts as well as ideas for improving public education. A wide range of information sources were reported, with central and regional government, emergency services (e.g., Police or Fire and Emergency), EQC, and TV/Radio the most common (see Appendix 2). Other prominent sources were GNS/GeoNet, social circles (friends, family, neighbourhood), and service organisations (e.g., NGOs, Red Cross). Only 67 participants (10.5%) reported not seeing or receiving any information about preparing for earthquakes. The most common information type received was about the impacts of an earthquake and how to plan/prepare for both earthquakes specifically and hazards generally. Many participants suggested using more channels, formats, and sources. Several of our interview participants suggested more posters in public

places (e.g., public transport, libraries), information signs in high hazard areas (e.g., for tsunami and flooding), and further efforts along the lines of the volcanic hazard exhibit at Auckland Museum (e.g., a portable version to take to schools).

Scope, Limitations, and Assumptions

There are limitations to this research which are important to note as they provide context to the results and interpretations. Firstly, while we might expect similar patterns of findings in other low(er) seismic hazard zones in Aotearoa New Zealand, it may not be safe to assume that residents of all regions perceive and prepare for earthquake risk in the same way. Related to this point, the Auckland Region itself is large and diverse, so more work is needed to understand to what extent the findings presented here are representative of all or some of the population. Further, our use of convenience sampling means that our study samples are not fully representative of the population within the general region, skewing young and with Māori and women underrepresented.

One of the challenges of conducting this type of work is the unpredictability of natural hazard events. This survey in Phase One of this research was launched the day before the January 2023 Auckland Anniversary floods, which caused widespread disruption, power outages to over 25,000 homes, billions of dollars of damage, and four fatalities. Given that one of our key research questions was the impact that salient and recently-experienced hazard events have on earthquake perceptions, the survey had to be suspended (it was relaunched on the 30th of June) to avoid bias in the data. While we were eventually able to turn this into an advantage by pivoting to a natural experiment design (comparing those who were and were not impacted), these significant events did have a meaningful influence on our participants in both the survey and the interviews such that our findings may represent a snapshot in time. Future work should explore how these perceptions change over time and context.

Discussion

This research was designed for Phase One (survey, quantitative analysis) and Phase Two (interviews, qualitative analysis) to complement each other and lead to more nuanced understandings of the questions driving the research, as described above. As such, this section will briefly present findings from the survey followed by the interviews, and then discuss both holistically in terms of how the combined results address the research objectives.

Phase One: Survey

Preparing and barriers to preparing

Across the full list of presented preparation actions, there was little variance in the proportion who had taken the action for the purpose of an earthquake, taken the action for another hazard, might take the action, and will not take the action (Appendix 2, Table 1). Typically, slightly more participants had taken actions for another hazard than for earthquakes (except for a few actions which are explicitly earthquake-related, in which case the proportions were more equal), and about as many thought they might take the action in future as had already taken the action (either for earthquakes or another hazard).

All of the presented barriers to preparing were scored relatively similarly (a range of 4.23 to 4.89 on a 1 to 7 scale; Appendix 2, Table 2), suggesting that none are particularly prominent over the others. However, linear regression showed that of these barriers, having other things to think about, perceived need for co-operation with others, the belief that it is others' responsibility to prepare for and mitigate earthquake risk,

and the belief that preparing for earthquakes won't help were significantly negatively associated with earthquake preparation. These barriers, therefore, may be key to target in communication. The barrier of having other things to think about, belief that it is others' responsibility to prepare, and that preparing won't help have been demonstrated in previous research in high-seismic hazard areas (McClure et al., 2015b; Paton et al., 2005; Vinnell et al., 2021b). However, it is useful to find evidence for their relevance in relation to earthquake preparation in a lower-seismic hazard area.

Spatial comparisons

Perceived likelihood of a damaging earthquake in Auckland was positively associated with preparation as expected. Counter to expectations, beliefs that earthquakes are more likely somewhere else in NZ was not associated with earthquake preparation, either negatively or positively. Further, among those not impacted by severe weather, perceived likelihood of a damaging earthquake in all higher-hazard areas was not related to preparation in Auckland, contrary to our expectations that we would find a negative relationship. However, amongst the group of participants who *had* been impacted by severe weather, these perceptions of likelihood in higher-hazard regions were positively, although weakly, associated with Aucklanders' earthquake preparation.

It is possible that the severe weather events caused a baseline decrease in hazard perceptions, including earthquakes; the group who were not impacted likely best represent typical beliefs and therefore suggests that spatial comparisons are not particularly important in how Aucklanders think about their seismic hazard.

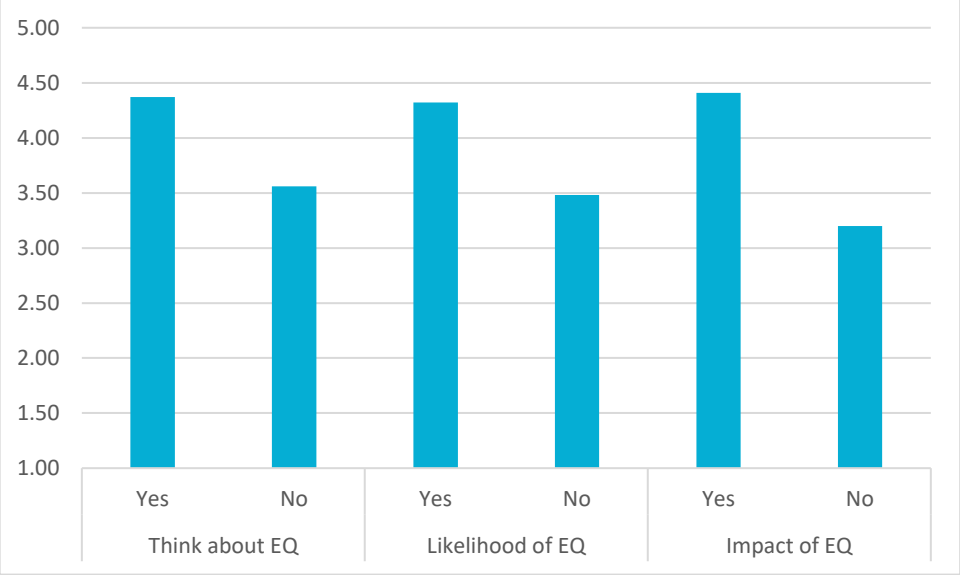
Hazard comparisons

Participants were asked to directly compare nine hazards (earthquakes, volcanoes, floods, storms, disease outbreaks, tsunami, drought, bushfires, and landslides) on three factors: how often they thought about them, how likely they thought it was that the hazard would impact them, and how severe they thought the impacts would be if they did occur. The nine hazards were ranked against each other from 1 (the most) to 9 (the least), such that lower numbers mean higher risk perception. Across the full sample, earthquakes were the most thought about, seen as the most likely, and seen as having the most severe impacts while volcanoes were the lowest (Appendix 2, Table 3). These findings are counter to the expectation that earthquakes would not be highly perceived given their infrequency in the area, while volcanoes would be highly rated given their salience (e.g., prominence in the landscape of volcanic cones). It is important to note that the mean scores had a narrow range and a high standard deviation; the former suggests that differences in perceptions of the hazards were small and the latter that there was limited consensus among the sample. It is likely that there are meaningful confounding variables which need to be considered when analysing hazard comparisons, including personal experience, location within Auckland, and sociodemographics.

It is also likely that the North Island severe weather events in the first half of 2023 influenced hazard perceptions amongst our sample. While this bias is potentially problematic, it also presented an opportunity to test the impact of recent experience of one hazard on perceptions of others. In particular, we saw that people who were negatively impacted by severe weather in the six months before the survey thought about earthquakes significantly less, saw their likelihood as significantly lower, and thought the impacts would be significantly less severe than those who were not impacted by those weather events (Appendix 2, Table 4). Being affected by the severe weather increased the frequency of thinking about floods as well as the severity of impacts as would be expected, although did not influence perceptions of likelihood; it is probable that the extensive media coverage of the events meant that even those who were not impacted were aware that they occurred, and so their perceptions of likelihood would have also been influenced.

Figure 1

The impact of recent severe weather experience on Aucklanders' earthquake-related judgments



Note. Yes/No refers to having recent severe weather experience. Lower numbers indicate stronger perceptions (i.e., greater frequency of thinking about earthquakes, perceptions of likelihood as higher, and perceptions of impacts as more severe). All differences are statistically significant.

Interestingly, there were few other significant impacts of severe weather experience. Those who were impacted saw tsunami as significantly more likely and thought about bushfires significantly less than those were not impacted. It is possible that flood inundation was seen as similar to tsunami, and counter to the possibility of bushfire. The hypothesis behind these findings is that people may have a limit to the amount of perceived threat they can cope with, and so after experiencing one hazard, cognitively downplay others to avoid becoming overwhelmed; it may be that only earthquakes were salient enough and/or perceived as dangerous enough to trigger this cognitive mechanism. However, future research should explore why earthquake perceptions in particular were so strongly impacted by severe weather experience.

Communication

Appendix 2 Table 5 presents the number of participants who reported getting information from particular sources, what type of information they had received, and suggested improvements to existing communications. A wide range of sources were reported, with the least common being schools, despite 64% of participants reporting that they live in a family household which includes children. Other uncommon sources were community groups, marae (perhaps a reflection of the sample), and businesses. All three of these sources present potential avenues for increasing communication efforts. For example, research has shown that providing materials in schools can lead to increased household preparation (Ronan et al., 2008). The most commonly cited sources were official government and science agencies, including central and regional government, emergency services, EQC, and GNS/GeoNet. Several media sources were also frequently reported, including TV/radio, newspapers, and social media. A considerable number of participants also reported getting information through social networks such as friends, family, and neighbours.

The type of information received was fairly consistently spread, with the most common being information about the risks and impacts of earthquakes, how to plan/prepare generally as well as for earthquakes specifically, and what to do during shaking. Fewer (but still over 200; 31.8%) participants reported receiving information about what to do after shaking, while the least common type of information received was about

the science of earthquakes. It is encouraging that very similar numbers of participants had received information about how to prepare as had received information about the impacts of earthquakes; while it is necessary for people to believe that a hazard may impact them in order to want to act, this information needs to be paired with steps that people can take to prepare (Vinnell et al., 2021b).

Although many participants reported receiving various types of information from a range of sources, a meaningful number indicated that there were areas in which they thought communication could be improved. Only 14 participants (2.2%) felt that the information currently being provided was adequate. In particular, participants indicated that availability through different channels, in different formats, and from different sources could be improved. Greater personalization and detail were less, but still meaningfully, desired. Similarly, 129 participants (20.2%) said that information could be provided in more languages. It is possible that among subgroups within the wider Auckland region some of these communication needs may differ. While these findings are informative, like many described above the survey data is only able to answer part of the question. For example, it is useful to know that over half of the sample want to see information communicated through different channels, but further data collection was necessary to understand what those channels might be. For that reason, the second phase of this research involved qualitative data collection and analysis.

Phase Two: Interviews

The original plan in this research was to complement the quantitative survey described above with focus groups, with the primary aim of developing potential improvements or additions to communication strategies. Focus groups were seen as appropriate for this purpose as they can tap into collective sense-making and lead to more fully developed ideas as participants can interact with each other (Wilkinson, 1998), and they allow for testing of new material (Breen, 2006). However, several findings in the survey were unexpected and required further data to understand. This did not require group interaction and involved relatively straightforward questions, so focus group methods were deemed no longer appropriate (cf. the arguments of Parker & Tritter, 2006, that focus groups should only be used for collective generation and exploration). Instead, semi-structured interviews were chosen and conducted in June, 2024 (see Appendix 3). This method allowed us to target some of the less-clear findings from the survey as well as providing the opportunity to explore an individual participant's train of logic or reasoning in much more depth than a focus group would allow.

Hazard perceptions

Of the eight interview participants, all but one mentioned volcanoes when asked which three natural hazards they thought would be the most impactful on them. Rain and flooding were also mentioned by seven participants, with three mentioning tsunami and only two listing earthquakes in their top three hazards. When asked about which of those hazards they were most concerned by, the most common answer was volcanic eruption (three participants), with a further three participants saying flooding or climate change (due to its impacts on increased rainfall). Of note, two of the participants who said that volcanoes concerned them the most commented that if they had been asked in 2023, they would have said flooding. This suggests that volcanoes are a prominent *consistent* hazard, while concern about flooding depends on the recency of extreme events. One participant, who lives near the coast, said that tsunami concerned them the most, while the final participant said that they were not worried about any natural hazard. One point to note about perceptions of volcanic risk is that several participants assumed that the next eruption would occur at one of the existing cones in the Auckland Volcanic Field. This is in contrast with the fact that an eruption could occur at any previously undetermined location in Auckland (Ang et al., 2020), perhaps suggesting that baseline understanding of volcanic processes in Auckland could be improved.

Earthquake experience seemed to have a mixed impact on how people perceive and respond to their own earthquake risk in Auckland. The participants had a diverse range of experience, from someone who had never felt an earthquake, to minor-moderate experiences of New Zealand earthquakes, through to one who had experienced a M8.8 overseas. Two participants noted that they felt they and others should have more knowledge about earthquakes, in particular "how to react when earthquakes happen" and better participation in drills. Two participants were less worried about earthquakes because they had lived in areas of higher risk (one in Wellington, one overseas), while a further two participants reported the Canterbury Earthquake Sequence had heightened their perceptions of risk in Auckland. As one of them explained, because "everyone" had said the next big earthquake would be in Wellington, the Canterbury earthquakes made them realise that earthquakes are possible anywhere, not just where they might be the most likely.

Relatedly, participants were asked where they thought the next "big one" in New Zealand would be located. Seven participants said Wellington, with two also saying Christchurch and one also saying Hawke's Bay or Gisborne. The one participant who did not say Wellington said that the Canterbury Earthquake Sequence led them to believe that the next big one would be near Christchurch again, or another part of the South Island. This participant did not seem to know about the risk of the Alpine Fault, rather seemed to base their judgment on recent events. For most people, the belief that the next earthquake will not be in Auckland led them to feel better and more relaxed about their risk. One participant thought that many Aucklanders were not prepared enough for earthquakes, while another commented that they thought recent earthquakes in other parts of the country had made people in Auckland excessively concerned about their seismic risk. Only one participant said that the belief that Wellington will be the location of the next big event made them more worried about their risk in Auckland; they explained that because the hazard was higher in Wellington, more steps had been taken to address it. The example they provided was the labelling of earthquake-prone buildings, the absence of which in Auckland meant it was difficult to know how dangerous some of the city's older buildings might be.

Preparation

Several participants were confident that they would be able to support themselves for at least a few days after an event. Six reported having some basic survival supplies such as food, water, torches, radios, and means to cook. Three participants had identified their main hazard and evacuation routes for flooding or tsunami, while a further participant had deliberately considered natural risks when choosing where to live and therefore believed they were not located in any hazard zones. Only one participant said they had taken preparation steps specifically in response to earthquake risk, and that was because they had first taken those actions in Wellington and had decided to repeat them after moving to Auckland. One participant noted that "you kind of end up in the same scenario after all of these things… have a big overlap of what you need to do" so they had not prepared for a specific hazard. Two participants had taken no preparation action because they believed that there would be advanced notice or that they would be able to cope "in the moment". Two participants noted that they knew the importance of planning for toileting if the wastewater system becomes unavailable but had not taken any steps on this point because they were unsure of exactly what to do.

Views on the preparedness of official agencies (e.g., Auckland Council/Emergency Management, emergency services) were mixed, from "not very good" through to "pretty good". Several participants expressed that they felt there had been improvements following the January 2023 Anniversary floods, although others disagreed that lessons had been learned by the Council. Particular concerns included resiliency of infrastructure such as roads and insufficient rigour in resource consenting in high-risk areas. Two participants felt that official agencies were well set up to carry out response activities such as evacuation, though again other participants directly disagreed, with one saying "on paper they're prepared, but maybe when it comes

to the actions of what to do, not so prepared" based on their experiences such as not knowing where their local "civil defence point" is located. Across the interviews, the participants reported that the flooding events of 2023 showed the importance of communication (e.g., sending messages to phones), visible leadership, and improving partnerships with iwi. This latter point included better applying indigenous knowledge of past events as well as better appreciating the role that marae play in a response capacity.

Communication

Participants reported a range of different channels through which they had received information about natural hazards, including posters in a school for speakers of English as a second language, in hospitals, and at the library. The most reported hazard covered was earthquakes, and in particular what actions to take during shaking (e.g., "Drop, cover, and hold"). Other participants had seen information about tsunami specifically or emergencies generally. Three participants specifically mentioned receiving the test messages from the Emergency Mobile Alert and appreciating the system. Generally, participants were not particularly good or confident in recalling the source of information they had heard or seen, but this did not appear to negatively impact their opinions about that information. Only one participant reported seeing videos (on YouTube), one had received a pamphlet in the mail, and one had collected a water storage container from a Council initiative they had seen promoted in the local paper. Three participants mentioned the volcano hazard exhibit at the Auckland War Memorial Museum with extremely positive opinions; one participant commented that as a child it was "the coolest thing [they'd] ever seen", although also noted that it had left them terrified of volcanic eruptions. Extreme fear responses can inhibit preparation actions (Weinstein et al., 2000), so it is important to ensure such initiatives strike a balance between communicating hazard impacts but also providing information about mitigation, reduction, and preparation to ensure people are motivated but also empowered to act.

Most participants had some idea of where they could go to get more information, with sources cited including GeoNet, GNS, Council, EQC, and Emergency Management. Types of information desired included the likelihood of events, evacuation routes for flooding/tsunami, and what to do when a volcanic eruption is expected or starting. Other suggestions for improvement included providing information specifically to new arrivals into New Zealand/Auckland (two participants), more face-to-face community events (four participants), and more posters in public places such as buses, trains, and malls (four participants). Other suggestions included more signage about flooding and/or tsunami hazard and evacuation near the water (three participants), promoting social media pages (with considerations for targeting advertising to people using VPNs), developing the Auckland Museum volcanic hazard exhibit either through expansion to include other hazards or making a mobile version to take to places like schools and malls, and better communication with rural communities such as plans for multiple access routes to avoid those communities being isolated.

Overall Findings

Hazard perceptions

In the survey, earthquakes were ranked highest on average for how often they were thought about, perceived likelihood, and perceived severity of impacts, while volcanoes were ranked the lowest on all of these factors, suggesting that earthquakes are perceived as a far more pressing hazard for Aucklanders. However, in the interviews, only a quarter of participants said that earthquakes were in the top three of hazards they thought could impact them or concerned them in Auckland, while volcanoes were named by all but one participant. These conflicting findings show the importance of approaching the same question with multiple methods and data types, to gain a clearer understanding of the answer. In this case, further

research is needed to clarify how *most* Aucklanders think about their hazards. Such future work should in particular aim to achieve a sample which is more reflective of the region's cultural diversity.

Similarly, more work is needed to understand both the role of spatial and hazard comparisons. For example, it is unclear why the severe weather events may have significantly impacted risk perceptions for earthquakes but (largely) no other hazard. The role of spatial comparisons is also likely more context-dependent and individual than originally hypothesized; the lack of a clear pattern in the survey is at least partially explained by the finding of both positive and negative influences in the interviews (i.e., instances where perceptions of high earthquake risk in other parts of the country lowered and instances where it heightened perceptions of risk in Auckland).

Preparation

As is often found (e.g., Vinnell, 2020), all preparation actions had been taken by fewer than 50% of the survey participants. Similar proportions of participants had taken each action (for either earthquakes or another hazard) as those who indicated that they might take that action, showing the common issue of translating intentions into actual behaviour (Vinnell et al., 2021b). All barriers to preparation were rated fairly consistently, suggesting that none are particularly prominent in the context of Aucklanders' preparation for earthquakes. Also of interest, we found that very similar proportions of participants had taken actions across the different categories (e.g., survival, mitigation, structural, planning, community). Typically, survival actions are considerably more common than other types of preparation actions (McClure et al., 2015b). This more typical pattern was seen in the interviews, where participants more often reported survival actions such as storing food and water and having camping-type gear, with the next common type being emergency planning (e.g., learning hazard zones and evacuation routes).

The mean preparedness rating for Auckland Council/Emergency Management was 5.06, just above the midpoint of the 1-7 scale. Interestingly, those who were impacted by severe weather saw Council as statistically significantly more prepared to deal with an earthquake (M = 5.15) than those who were not impacted by the 2023 severe weather events (M = 4.68). While this is not a large difference, it is supported by the comments of several interview participants who had been impacted by the flooding and felt that lessons had been learned.

Communication

Survey participants reported receiving a wide range of types of information from a wide range of sources, as well as potential ways to improve communication, suggesting that existing efforts are working but can be altered or expanded to better reach and better convey key information. Interview participants provided several suggestions as described above; some of these may not yet be implemented, while others may already exist and could perhaps be increased to widen their reach.

Conclusions

1. A main conclusion of this research is that the way in which Aucklanders think about, perceive, and act on their earthquake risk is complex, likely being context-dependent and individualised. For example, earthquakes were rated highest amongst our survey participants but were mentioned by fewer interview participants than volcanoes, weather, and tsunami. Auckland may be too large and too diverse in terms of geology, geography, hazard profiles, hazard experience, and sociodemographics to consider as a single research population. The diversity of population in Auckland, and the difficulty of engaging and communicating with people within such a diverse setting, is shown in earlier studies from the region (Ballantyne et al., 2000; Paton et al, 2000). These studies recommend working at a local level to build trust with specific groups (e.g., communities of interest, communities of location), with an aim of identifying and addressing hazard issues relevant to the specific context in which such groups are situated (Paton et al., 2024).

Recommendation One: Future work should target specific groups within the Auckland region (e.g., geographical areas, communities) to investigate influences on building earthquake resilience, especially if communication efforts and hazard profiles also vary between these groups.

2. One of the clearest patterns of findings is that the severe weather events of 2023 impacted how participants perceived other hazards. In the survey, experience of severe weather significantly reduced perceptions of seismic risk, while some interview participants indicated that the events led to flooding (temporarily) superseding volcanoes as the hazard that most concerned them. Caution should be taken when communicating to people about a specific hazard when they have recently been impacted by a different one. This includes a consideration of ethical responsibility to avoid harm through increasing or revisiting potential trauma, but also a consideration of how the recent experience might temporarily alter hazard perceptions, potentially making people less receptive to messages about hazards other than the type which most recently occurred. Previous research has shown that post-event is an important window in which to try to encourage preparation action as salience and beliefs about the importance of preparing are temporarily heightened (Vinnell et al., 2019), but it may be that this benefit is limited to the specific hazard which was experienced. Within the hazard itself, it is also important to consider which impacts people experienced, as previous research has shown that in the immediate post-event window people are likely to prioritise actions related to ways in which they were affected (Doyle et al., 2018).

Recommendation Two: Communication campaigns following events should either focus on preparation for the specific hazard experienced or be targeted towards actions which would help for that hazard as well as others (e.g., if strong winds led to widespread power outages, encouraging steps to be prepared for power cuts regardless of their cause). These decisions should be informed by additional evidence around the relative effectiveness and efficiency of different hazard and impact foci in the crucial post-event window.

3. Views were somewhat mixed on the preparedness of official agencies to respond to a large-scale event such as a strong earthquake. This includes perceptions of whether those in charge of response have identified, learned, and applied lessons from the 2023 severe weather events. Trust in official agencies, such as perceptions of their ability to learn from and correct mistakes, is important in both community preparation as well as response (Paton et al., 2024).

Recommendation Three: Official agencies such as Auckland Council/Emergency Management could consider public outreach to communicate what lessons have recently been identified and the steps which have been taken to implement those learnings. Future work could also explore how perceptions of public agency preparedness influence personal preparation actions, as previous evidence is often conflicting with neutral, negative, and positive effects having been found (Vinnell et al., 2021a).

4. Over half of the survey participants indicated that they would like to see information communicated through more channels and in more formats. They also reported wanting to see information from more sources, although few interview participants could recall who had provided the information they had already seen or received. Our interview participants offered several suggestions for what they would like to see in public education.

Recommendation Four: Public education providers could review their existing products to see whether they include mechanisms desired by participants, in particular posters in public places, face-to-face community events, and tsunami/flooding signage in hazard zones, to identify whether these could be expanded if they are currently in use, or introduced if they are not.

5. Regarding earthquake risk specifically, there was conflicting evidence between the two research methods and samples. While awareness of earthquake risk was high in the survey, only two interview participants cited it in their top three natural hazard concerns. The survey also showed that levels of preparedness had meaningful room for improvement, and no particular stand out barrier in terms of inhibiting preparedness actions.

Recommendation Five: It will be important to better understand the nuances of earthquake risk awareness and perception in Auckland before making decisions around specific interventions such as aiming to motivate structural mitigation actions. However, existing public education can build on knowledge that the public may already have, such as a general awareness that earthquakes are possible in the Auckland region.

Future Work

As noted above, it became clear during the interview stage in particular that it is difficult to consider Auckland as a single population; the diversity in demographics as well as hazard profiles suggests that future work should explore seismic risk perceptions at more localised levels. Ideally, this would include considerations of particular sociodemographic groups, including recent arrivals to Auckland and/or NZ and ethnicity groups who may be at greater risk.

Given the scale of the extreme weather events in Auckland in 2023, which included six fatalities, 3,000 homes unable to be returned to, and 40,000 further households needing assistance (Tāmaki Makaurau Recovery, 2024), future research should explore in more depth and over time the impact of these events on hazard perceptions and behaviour. While influences of previous events on preparation behaviour have been shown to disappear over a span of months (Vinnell et al., 2019), other research shows that significant series of events (such as the Canterbury Earthquake Sequence, and potentially the series of five severe weather events within a four-month period in early 2023 in Auckland) can have much longer-term impacts (Becker et al., in press).

Outputs and Dissemination

1. Poster to be presented at the 2024 QuakeCoRE Annual Meeting in Ahuriri, Napier, September: "Exploring influences on building earthquake resilience in lower seismic hazard zones" (abstract accepted)

2. Workshop to be conducted at the annual DEVORA forum in Tāmaki Makaurau, October to share and solicit feedback on the key findings of this research project

Publications and Communications

1. Co-wrote media release with Toka Tū Ake communications team to promote survey recruitment: https://www.naturalhazards.govt.nz/news/understanding-perceptions-about-natural-hazards-in-lower-seismic-areas/

2. Vinnell, L. J., Johnston, D. M., Becker, J. S., Doyle, E. E. H., Lindsay, J., Orchiston, C., Tapuke, K. (2024, draft). Earthquake risk perceptions and preparation in low(er) seismic hazard zones: The role of spatial comparisons and hazard experience.

3. Vinnell, L. J., Johnston, D. M., Becker, J. S., Doyle, E. E. H., Lindsay, J., Orchiston, C., Tapuke, K. (2024, draft). Natural hazard perceptions, preparation, and communication needs in Tāmaki Makaurau, Auckland.

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Appendices

Appendix 1: Phase One Survey Method

Design

This study used a cross-sectional approach, with a single questionnaire conducted online at a single point in time. However, the Auckland Anniversary rainfall event of January 2023 and subsequent events which impacted Auckland (e.g., Cyclone Gabrielle) allowed for a natural experiment comparing those who were impacted by severe weather in the preceding 6 months to those who were not in terms of key outcome measures (in particular, risk perception and preparation for various hazards, including earthquakes).

Materials

The full survey can be found on the Open Science Framework (https://osf.io/v35cj/). The survey was shared with relevant local stakeholders, including Auckland Emergency Management, for feedback prior to data collection. This study was evaluated by peer review and judged to be low risk, so a notification of the study was filed with Massey University in accordance with the due process for that institution. The survey was launched on the 30th of June, 2023 and ran for two weeks.

Participants

Participants were recruited using convenience sampling; the link to the online survey, hosted on the Qualtrics platform, was shared on various social media platforms and where possible targeted to Auckland (e.g., by posting in geographically bound Facebook community groups). Seven-hundred and seventy-one people opened the survey. Two screening questions before the survey excluded 82 people who were either under the age of 16 or did not answer the question and a further 101 who either did not live in Auckland or did not answer the question. Many of these participants overlapped, leading to a sample of 670 who passed the screening questions. A further 32 participants did not answer any further questions and so were also excluded from the data set. The final useable sample included 638 participants. Of these, not all participants answered all questions, so the sample sizes for some individual analyses may be lower.

A third (33.7%) were born in a country other than NZ, with most identifying as a New Zealander (62.4%) or European (15.2%), followed by Samoan (6.3%), Tongan (4.4%), Māori (4.4%), and Cook Islands Māori (3.9%). Men represented a slight majority (55.4%) of the sample, with no participants identifying as a gender other than man or woman. The mean age was 33 years, with a range between 17 and 78 years old. The most common living situation was in a family with children (64.4%), followed by family without children (22.4%), or alone (8.9%). Participants had lived in their suburb for an average of 14.18 years, with a range from less than a year to 63 years.

Appendix 2: Phase One Survey (June/July 2023) Results

Table 1

Earthquake Preparation, Reduction, and Mitigation Actions

	Done for earthquake	Done for another hazard	May do this	Will not do this
Stored at least three litres of water per person, per day for three days	15.7	26.6	50.8	6.9
Set aside three days or more worth of food specifically for an emergency	15.1	32.4	39.2	13.3
Checked the contents/operation of my emergency supplies at least every six months	18.0	28.6	42.8	10.6
Have a supply of essential medicines for illness or allergies	15.6	29.0	43.4	12.1
Have access to an alternative cooking source (e.g., gas barbeque)	15.2	31.5	40.4	12.9
Have the means to boil water if necessary or to treat it with purifying tablets	14.4	29.3	45.3	11.0
Retrofitted the non-structural elements of my house to increase its earthquake resistance	19.4	25.1	38.1	17.4
Made sure that moveable items are stored safely in cupboards with latches	17.4	26.1	48.3	8.2
Secured items in my house (e.g., furniture, hot water cylinder)	16.1	25.1	44.1	14.7
Made sure every adult in the household knows how to, and has the means to, turn off essential services	15.0	28.0	45.9	11.0
Have spare batteries for appliances I might need to use	15.4	30.5	42.5	11.6
Have a working battery torch (or solar/dynamo equivalent)	18.5	27.3	43.9	10.3
Have a working battery radio (or solar/dynamo equivalent)	15.9	27.1	42.5	14.5
Purchased or put together a first aid kit	18.6	25.5	44.8	11.1
Made sure each family member has an emergency get away kit in case we have to evacuate quickly	17.1	27.6	47.0	4.8
Prepared a household emergency plan	18.5	25.0	43.1	13.4
Regularly update my emergency survival items	16.9	28.5	41.5	13.1
Discussed with my family and clearly outlined what would happen in the event an earthquake occurred while we were at work/school	18.8	26.2	43.5	11.6

Prepared additional supplies at work and/or in my car in case I am away from home	19.2	25.4	42.7	12.8
Undertake training that might assist in a disaster (e.g., first aid)	16.9	25.6	44.9	12.6
Encouraged other people in my community to get prepared for earthquakes	18.4	21.8	42.7	17.2
Worked with a community group to increase earthquake awareness and preparedness	19.0	26.2	43.3	11.6
Worked with others in my neighbourhood or community to develop an earthquake response plan	17.8	24.5	40.1	17.6
Avoid earthquake prone buildings (e.g., to live in, work in, or visit)	21.6	24.8	39.7	13.9
Obtained house insurance with earthquakes in mind	17.5	25.9	42.2	14.5

Note. Numbers in this table are percentages of the sample of who indicated each response for each item.

Table 2

Influence of Barriers to Preparation

Barrier	*M*	*SD*
The cost is too high	4.64	1.56
Not enough of the skill or knowledge required	4.59	1.55
Not enough time to prepare	4.63	1.52
There are other things to think about	4.85	1.43
Need for co-operation with others	4.77	1.48
Compliance with building regulations	4.89	1.47
Belief it is others' responsibility to prepare	4.67	1.57
Not getting around to it	4.51	1.63
Risk from earthquakes is too low	4.48	1.67
There are more risky hazards to focus on	4.71	1.51
Not thinking about it	4.35	1.65
Earthquakes are too destructive to bother preparing	4.23	1.74
Preparing for earthquakes won't help	4.32	1.79
Earthquakes are more likely somewhere else in NZ	4.61	1.57

Note. The scale used for these questions ranged from 1 (Not at all) to 7 (A great deal).

Table 3

Hazard Comparative Rankings

	Think		Likelihood		Impact	
	M	*SD*	*M*	*SD*	*M*	*SD*
Earthquakes	4.19	2.76	4.17	2.76	3.94	2.75
Volcanoes	5.68	2.52	5.79	2.51	5.38	2.69
Floods	4.61	2.59	4.50	2.44	4.89	2.46
Storms	5.00	2.54	4.91	2.54	5.08	2.44
Disease outbreaks	4.58	2.58	4.50	2.57	5.06	2.67
Tsunami	5.25	2.42	5.23	2.53	4.97	2.54
Drought	5.34	2.58	5.43	2.57	5.34	2.54
Bushfires	5.21	2.50	5.35	2.50	5.03	2.41
Landslides	5.14	2.44	5.13	2.41	5.31	2.45

Note. Participants were asked to rank the hazards from most (1) to least (9), such that lower numbers = a higher comparative ranking

Table 4

Hazard Comparative Rankings Comparing Those Impacted and not Impacted by Severe Weather

	Think about hazard		Likelihood of hazard		Impact of hazard	
	Yes	No	Yes	No	Yes	No
Earthquake	4.37	3.56	4.32	3.48	4.41	3.20
Volcanoes	5.69	5.54	5.76	5.80	5.36	5.38
Floods	4.53	5.09	4.47	4.65	4.74	5.48
Storms	4.95	5.10	4.83	5.25	5.06	5.18
Disease	4.55	4.77	4.48	4.52	5.12	4.81
Tsunami	5.18	5.44	5.13	5.66	4.94	5.01
Drought	5.35	5.33	5.37	5.64	5.27	5.65
Fire	5.31	4.84	5.43	5.13	5.07	5.03
Landslides	5.06	5.33	5.21	4.86	5.30	5.27

Note. Highlighted cells indicate where there is a statistically significant difference between those impacted ("Yes") and not impacted ("No") by severe weather in the previous six months. Participants were asked to rank the hazards from most (1) to least (9), such that lower numbers = a higher comparative ranking

Table 5

Information Sources, Type, and Desired Improvements

Source (Received information)		Type (Received information)	
No information received	67	Science of earthquakes	160
Central govt	258	Impacts	333
Regional govt	241	How to plan/prepare generally	332
Emergency services	243	How to plan/prepare for earthquakes	306
EQC	231	Risk of earthquakes	271
GNS	167	What to do during shaking	262
GeoNet	134	What to do after shaking	203
TV/radio	211	Other	1
Newspapers	126		
Meetings	67	Improvements	
Businesses	52	Languages	129
Schools	30	Channels	379
Friends/family	128	Formats	351
Service orgs	132	Sources	329
Neighbourhood	125	Personalisation	142
Marae	47	Detail	95
Work	78	Other	6
Posters	81	Already adequate	14
Phone book	53		
Insurance	76		
Social media	118		
Community group	43		
Other	2		

Note. Numbers are the absolute frequency of participants who selected in each option. For each question, they were able to select multiple options, such that totals exceed the sample size of $N = 638$.

Appendix 3: Phase Two Interview Method

EQC Auckland Interview Questions

Background

- What area of Auckland do you live in?
- How long have you lived in Auckland?
- Where did you live before Auckland?
- Do you have family in other parts of NZ or overseas?
- Do you have any family in Auckland?
- Are you responsible for any dependents (including pets?
    - If yes, are you able to briefly give details?
- How old are you?

Natural hazards in Auckland

Instructions to interviewee: For the following question, please *only* think about natural hazards in Auckland.

- When I say "natural hazards", what's the first thing that comes to mind?

Clarify if necessary for next questions.

- Which three natural hazards do you think will be most impactful on your area?
- Which natural hazards in Auckland are you most concerned about?
- Have you taken any steps to prepare for natural hazards?
    - If yes, what steps and for what hazards (if any specifically)?
    - If no, why not?
- How prepared do you think your local agencies (council, emergency management, emergency services) in Auckland are for a large-scale hazard event?
    - Why do you think that?

Earthquakes

Some of these questions may be a little uncomfortable – you do not have to answer them if you don't want to, and if you do answer them just provide as much information as you're comfortable with

- Have you ever felt an earthquake?
- Have you ever been negatively affected by an earthquake?
- Have you had any friends or family affected by an earthquake?
- Have any earthquakes influenced how you think about them, in any way? This could be ones you've experienced or ones that you've heard about for example in media coverage.
    - If yes, what about it influences you, and what impact did it have?
- Where in NZ do you think a large, damaging earthquake is most likely to occur?
    - If answer not Auckland: do you think that influences how you think about earthquakes in your own area?

Information

- Where do you get information about natural hazards, including earthquakes?
    - Does the information you've seen or received tend to deal with a single hazard (e.g., earthquakes specifically), or hazards more generally (e.g., talking about emergencies)?
    - Who provides that information?
    - What sort of information do you get? (for example, about the likelihood, the impacts, what you might experience, what you can do to be more prepared)
    - How do you tend to receive this information? (for example, TV, social media, face to face events)
    - What do you like about this information? (for example, how it's communicated, how it explains things)
    - What do you think could be improved in terms of how natural hazard information is provided?

Do you have any further comments you'd like to share about earthquakes [in your area]?

Design

This study used a semi-structured interview design, where questions were developed beforehand to address key research questions but there was inbuilt flexibility to pursue and elaborate on interesting responses. The questions for these interviews were given to the DEVORA Steering Committee for feedback, which included representatives from University of Auckland, Auckland Council, GNS, EQC, and iwi. Interviews were conducted in June, 2024, and ran for approximately 30 to 45 minutes. They were conducted online using Microsoft Teams. Autogenerated transcriptions were checked by the PI who also conducted the content analysis. The semi-structured nature of the interviews meant that participant responses were relatively unambiguous and did not require detailed interpretation (e.g., of emerging themes).

This study was evaluated by peer review and judged to be low risk, so a notification of the study was filed with Massey University in accordance with the due process for that institution.

Participants

Eight people participated in the interview study, including four women and four men, with ages between 30 and 69 years old. Participants were from a range of suburbs, including east, west, south, and central Auckland, and ranged in how long they had lived in Auckland from 2 years to over 50 years. Participants were Pākehā, British, Chilean, and Filippino. While this represents a good diversity for a small sample, future work should conduct similar interviews with other key demographics including Māori, Pasifika, and those from other Asian countries.