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Risk Perception of a Major Earthquake Event at the Cascadia Subduction Plate Boundary

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Key Points:

- Participants agree that there is a high level of public awareness on the geohazards related to the Cascadia Subduction Zone, however, the level of individual preparedness is unknown.
- Individuals preparing can strengthen communities as a whole.
- State governments need to prioritize updating infrastructure to seismic resistance codes and enhance preparation measures with specific consideration to extra vulnerable populations.

Abstract

The Cascadia Subduction Zone (CSZ) is a tectonic plate boundary that is located about 64 to 128 kilometers off the west coast from Northern California to Vancouver Island, British Columbia (Cascadia Region Earthquake Workgroup, 2013). Subduction faults are on a cycle of a pressure build up then quick release, materializing as a megathrust earthquake. These faults have the potential to produce earthquakes of the highest magnitude. Paleoseismic studies and Native American oral history have proved that the last CSZ earthquake occurred in 1700 and likely had a magnitude of 9.0 (Finkbeiner, 2015, Nelson et al., 2006). Most probability analyses suggest that there is a 7 to 15% chance of a CSZ earthquake in the next 50 years (Lewis et al., 2007, Buylova et al., 2019). Is the Pacific Northwest prepared for a high magnitude earthquake and tsunami event? The purpose of the study is to document if and how individuals, communities, and town and state governments are preparing for the CSZ megathrust earthquake. A local seismology expert, two members of different emergency preparation and response groups, and a town official were interviewed. The interviews were recorded, transcribed, and compared. The six most commonly mentioned themes between the participants were identified and discussed. These themes include: (1) public awareness; (2) what motivates people to prepare; (3) community building; (4) cannot rely on government support; and (5) failing infrastructure and utilities. All participants believed that there is a high level of awareness of the geohazards involving the CSZ, however, awareness does not equate to taking preparation measures. Participants revealed different levels of risk perceptions and beliefs on how much individual preparation is necessary. Interpreting the interview data in our current societal context suggests that environmental justice and vulnerable populations' needs are important issues in the context of a CSZ earthquake and tsunami event.

Introduction

1.1 The Pacific Northwest of the United States is a geologically dynamic region, possessing rigid mountain ranges, active volcanoes, vast open spaces, and powerful rivers. The temperate climate nurtures old growth rainforests that blankets the land between the Cascade mountain range and the Pacific Ocean (Woodward, 2019). Located about 64 to 128 kilometers off the west coast of North America is the dense Juan de Fuca oceanic plate subducting under the less dense, continental North American plate (Nelson et al., 2006, Pacific Northwest Seismic Network). Known as the Cascadia Subduction Zone (CSZ), this fault stretches about 1,126 kilometers from Cape Mendocino, California to Northern Vancouver Island (Pacific Northwest Seismic Network). Subduction faults produce deep earthquakes with the potential to have the highest magnitude. As the plates converge, the more dense oceanic plate slides under the less dense continental plate at a rate of four centimeters per year (Cascadia Region Earthquake Workgroup, 2013). Where the two plates make contact, tension locks the two plates together causing the coastal land to uplift. This will occur until the frictional strength is exceeded by the built-up pressure between the two converging plates. When this happens, the sudden release of the built up strain will cause the overlying, continental plate to snap violently down and back into place, causing an earthquake of an epic magnitude. This coseismic subsidence can cause large portions of coastal land to drop as much as 2 meters (Cascadia Region Earthquake Group, 2013). It is possible for the plate to slip along the entire fault or only a portion (Nelson et al., 2006). Based on previous CSZ earthquakes, a full rupture would likely produce a 9.0 magnitude earthquake and trigger a tsunami that would drastically impact the west coast of America as well as the east coast of Asia.

1.2 The last time the CSZ experienced a megathrust earthquake was over three hundred years ago. The full length of the fault ruptured at around nine o'clock, Pacific Standard Time, on the night of January 26th, 1700. Most experts agree that it possessed a magnitude of 8.7 to 9.2 (Cascadia Region Earthquake Workgroup, 2013). The evidence of this earthquake can be found within seafloor sediment data (Hutchinson et al., 2017), through oral history from Native Americans and Japanese populations (Finkbeiner, 2015) and can be spotted by anyone on the Pacific Northwest coastline, if you know what to look for (Spitz, 2015). The Neskowin Ghost Forest in Tillamook County is one of many ghost forests scattered on the Cascadia coast. If you stand on the beach at low tide and look seaward, you will see hundreds of moss covered Sitka Spruce stumps, sticking out of the sand and water (Hale, 2019). These are remnants of a 2,000 year old forest that was a fatality of the 1700 earthquake as coseismic subsidence caused the entire forest to drop abruptly below sea level (Nelson et al., 2006, Spitz, 2015, Hutchinson et al., 2017). Stories of this event have been passed down through generations of different indigenous tribes up and down the Pacific Northwest, many tales specific enough to estimate a date and time that average near nighttime in late January, 1700 (Nelson et al., 2006). According to the Yurok tribe of coastal Northern California, "The earth would quake and quake again and quake again,

and the water was flowing all over” (Finkbeiner, 2015). Across the Pacific in Japan, tales of an ‘orphan’ tsunami, or tsunami in which no earthquake was felt before, was said to make impact on January 27th, 1700. The skeptics of evidence in the form of ancient tales or eerie tourist destinations will appreciate the scientific data that proves the 1700 earthquake.

Paleoseismologists, at many of the prestigious universities in the region, have extracted and studied local seafloor cores to date debris from earthquake-induced landslides. Dating the debris proved that the area experienced dramatic shaking in late January, 1700 (Hutchinson et al., 2017).

1.3 Examining the history of the fault helps us learn about the future of the CSZ. The 1700 earthquake was the most recent, however, far from the first of its kind. Subduction zones are always on a cycle of long term pressure accumulation, followed by a quick release. Evidence of megathrust earthquakes, based on paleoseismic studies of tsunami deposits and coastal subsidence found in sediment and seafloor cores, determines that over the last 10,000 years there have been 41 megathrust earthquakes (Oregon.gov). Dividing these numbers gives us the recurrence interval which is 243 years (Schultz, 2015). Using this model, the Pacific Northwest is 77 years ‘overdue’ for the next Cascadia slip. However, other models project that the recurrence interval is somewhere in between 300 and 500 years (Bodmer, 2018). One study suggests that the recurrence interval for a full rip megathrust is approximately 530 years (Buylova et al., 2019). Most probability analysis estimates that there is between a 7% and 15% chance of a CSZ earthquake in the next 50 years (Lewis et al., 2007, Buylova et al., 2019). Prediction models are based only on averages and scientists cannot predict when earthquakes will occur. The next CSZ megathrust could happen tomorrow or in five hundred years. The only given is that the next time the CSZ ruptures, it will be the most catastrophic one yet.

1.4 Since the 1700 megathrust, three major cities have been built in the region. There are skyscrapers, bridges, apartment buildings, and various infrastructure that serve over 16 million people who inhabit Cascadia (Cascadia Department of BioRegion, 2017). When Portland, Seattle, and Vancouver were developing, and up until the 1970s, no one considered the area as being seismically hazardous. The area does not experience frequent earthquakes like, for example, the residents of California do living near the active San Andreas and other crustal faults. Due to the lack of knowledge at the time, infrastructure was not built to withstand earthquakes. Only recently, in 1974, Oregon implemented their first building code that mandates some seismic resistance (Oregon Seismic Safety Policy Advisory Commission, 2013). Buildings that were built before that year are most likely not bolted down to their foundations and many have unreinforced masonry, meaning they are susceptible to collapse with even mild shaking. Over 75% of structures in Oregon will not survive the event (Schultz, 2015). A significant portion of the land is expected to undergo liquefaction (i.e., the strength of the soil weakens so it behaves like jello, unable to support infrastructure)(Cascadia Region Earthquake Workgroup, 2013). This will render many highways, railroad tracks, and airplane runways to be damaged

beyond use. The combination of the coseismic subsidence and tsunami will inundate most coastal towns and impact some inland towns. The Federal Emergency Management Agency director for Oregon and Washington said, “Everything west of Interstate 5 will be toast”(Schultz, 2015). Interstate 5 runs through northern California, Oregon, Washington, and British Columbia and is on average, roughly 60 miles inland from the shore and bisects most major cities such as Eugene, Salem, Portland, and Seattle. The Pacific Northwest will become unrecognizable after the next megathrust earthquake. When it comes to major natural disasters mitigation and preparation are key. Preparation efforts by individuals and households are equally as important as large scale mitigation efforts by town, state, and federal governments. The purpose of the study is to gain insight into if and how towns, communities, and individuals are preparing for the CSZ megathrust earthquake.

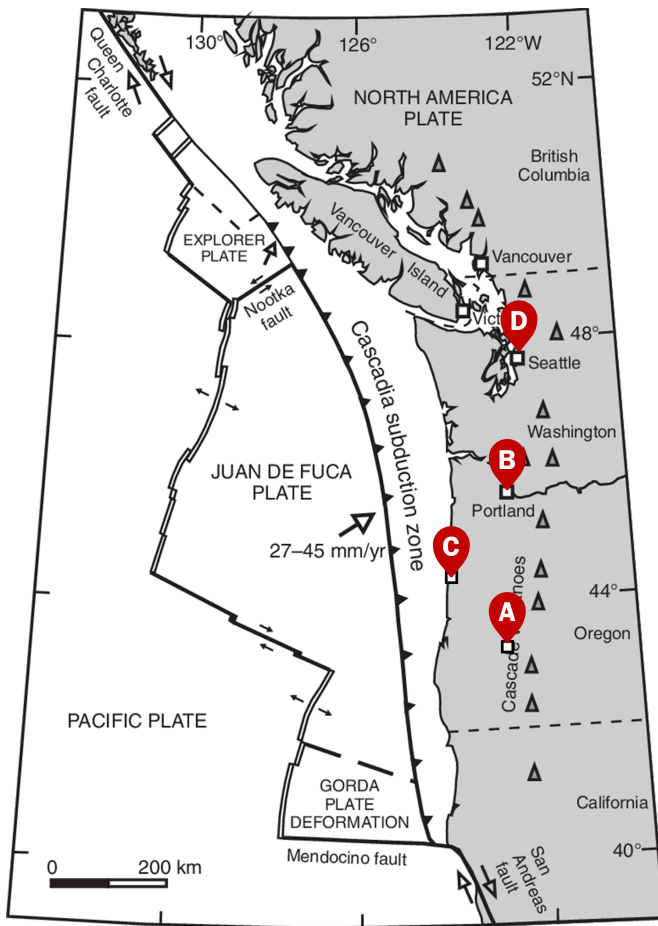


Figure 1. This map portrays the Cascadia Subduction Zone region and the location that the interviews took place with each participant (original image retrieved from Leonard et al., 2010 and edited by Michelle Kokes).

Methods

2.1 This study was conducted in consultation with the University of Rhode Island's Institutional Review Board. This project was granted IRB Approval 1527851-1 and was categorized as an Exempt Review. Data will be stored securely for three years and participants will remain anonymous.

Exploratory interview

2.2 Geology experts, members of emergency preparation and response groups, and town officials local to the Pacific Northwest were contacted via email and asked if they would agree to a short, in-person interview that would be recorded audibly. The participants did not receive compensation but were encouraged to participate as this study could help identify knowledge gaps between experts and promote better disaster preparation measures. These interviews were exploratory in nature, with questions geared toward understanding perception of risk associated with a megathrust earthquake and the level of preparation on the individual, community, and governmental scale. Four interviews were conducted with professionals that are involved with the geohazards of the CSZ in different ways (see table 1). Geology experts, members of emergency preparation and response groups, and town officials had separate interview questions, with some overlap for comparison purposes (see table 2).

Table 1. This table describes the different job positions of the four participants.

	Job Title
Participant A	Founder of a preparation group that specializes in infrastructure resilience in Oregon
Participant B	Founder of a small business that sells post earthquake supply kits to increase individual and community preparation
Participant C	County emergency manager for a coastal county in Oregon
Participant D	Research professor in the Seismology Department at large university in Seattle, Washington and manager of seismic network, tracking all seismic activity in the Pacific Northwest

Table 2. A list of questions for the three different categories of jobs. Participant A and B were asked the questions in the first column. Participant C was asked the questions in the second column and participant D the last column. Some follow-up questions were asked to have the participant either clarify or elaborate their answer(s).

Questions for members of emergency preparation and response groups	Questions for town official	Questions for local geology expert
What is your group's name and mission?	What is your job title?	What is your job title?
What work do you do involving the geo hazards in your area?	What work do you do involving the geo hazards in your area?	What work do you do involving the geo hazards in your area?
What populations are most at risk?	What emergency response plans does this town have in place for an earthquake/tsunami event?	Is it common knowledge in your academic community that the CSZ is due for a megathrust earthquake?
Do you believe that the CSZ is due for a megathrust earthquake?	What are the most at risk areas or populations?	Is it common knowledge in you local area that the CSZ is due for a megathrust earthquake?
Is it common knowledge in your local area that the CSZ is due for a megathrust earthquake?	Do you believe that the CSZ is due for a megathrust earthquake?	Is there any evidence contradicting the elastic rebound megathrust theory?
When do you believe the earthquake will occur?	Is it common knowledge in your local area that the CSZ is due for a megathrust earthquake?	When do you believe the earthquake will occur?
Are there enough regulations and emergency response plans in place to prepare for this event? If not what should be added?	How do you educate the public?	What will the Pacific Northwest look like after the CSZ earthquake?
How can individuals best prepare themselves?	When do you believe the earthquake will occur?	What role can geologists/seismologists play in minimizing risks associated with the CSZ?
How do you educate the public?	Are there enough regulations and emergency response plans in place to prepare for this event? If not what should be added?	Are there enough regulations and emergency response plans in place to prepare for this event? If not what should be added?
Any other comments?	How can individuals best prepare themselves?	How can individuals and communities best prepare themselves?
	What further research would you like to see done?	What further research would you like to see done?
	Any other comments?	Any other comments?

Identifying themes

2.3 After the interviews took place, the interviews were transcribed and common themes were identified. The themes were chosen by how closely they relate to the research objective and by the number of times that they were mentioned by the participants.

Results and Discussion

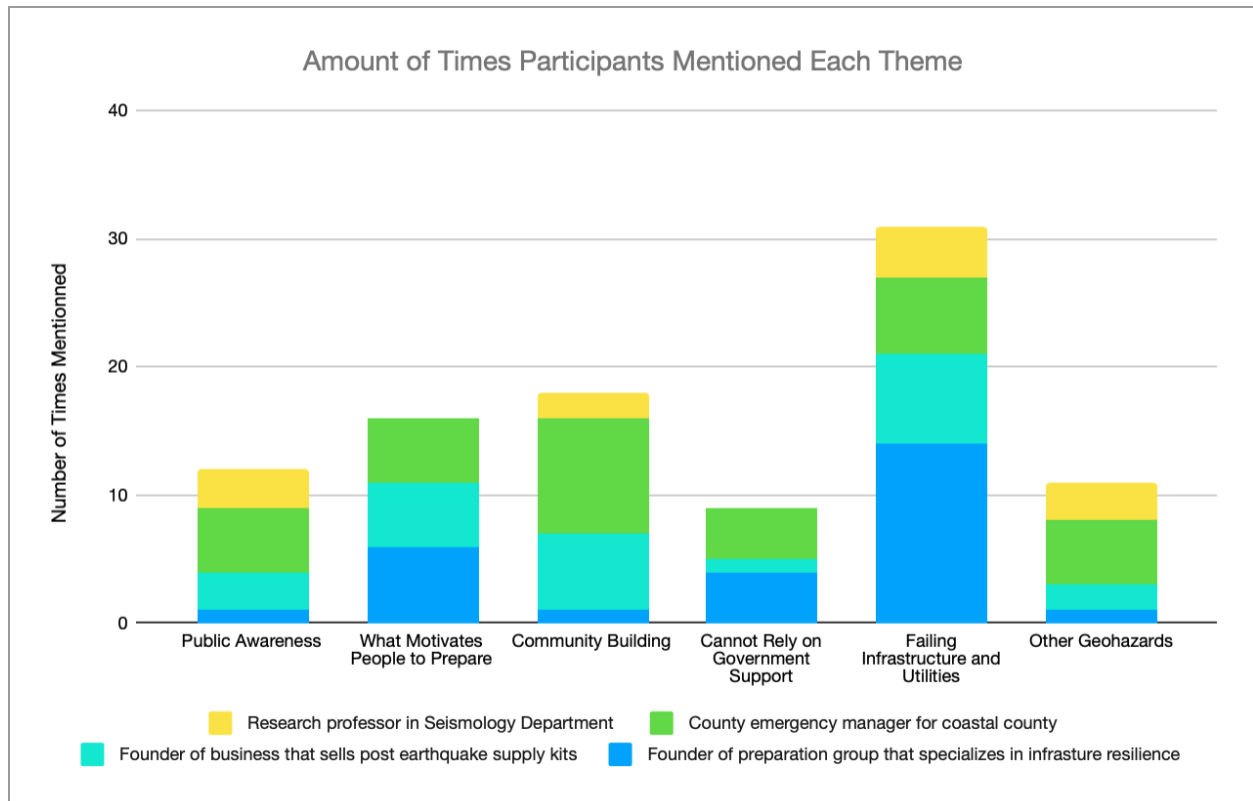


Figure 2. This figure represents the amount of times that each participant mentioned the six identified themes. It compares who mentioned which theme the most and which themes were mentioned more than others. These themes can be thought of as the main takeaways from each interview as well as the main takeaways of the collection of interviews. The total number of all mentions by the four participants was ninety-seven mentions.

Differences between participants

3.1 Interviewing people in varying areas of expertise involving the CSZ proved beneficial as they each offered a different perspective to the questions. Figure 2 measures how many times each participant mentioned the six themes. The results of each participant reflects their area of expertise. For example, the founder of a preparation group that specializes in infrastructure resilience (participant A) mentioned Failing Infrastructure and Utilities more than any other participant. The country emergency manager (participant C), the founder of a post earthquake supply business (participant B), and the founder of the infrastructure resiliency group (participant A), all work with geohazards from a humanitarian perspective. These three participant's work

aligned closely with my research objective as this study aims to understand human's risk perception. The seismology research professor (participant D) was an outlier as s/he considers the CSZ from a scientific perspective and may be disconnected with the societal implications of a megathrust. Though s/he is likely most knowledgeable on the fault itself, s/he did not have much insight on risk perception or the level of individual and public preparedness.

3.2 Participant's level of individual geohazard preparation varied. All participants stated that the CSZ megathrust earthquake and tsunami event could occur in their lifetimes, however, not all have taken preparation measures. Participant A stated that s/he have had their home seismically retrofitted, has an eight month supply of food for themselves and their spouse as well as a three month supply for their pets. In contrast, participant D has not taken any individual preparation measures specifically for the geohazards. S/he stated that their office is equipped with enough post earthquake supplies to service the staff for a while but at home, s/he has not taken any preparation measures for geohazards specifically. The other two participants did not comment on personal preparation.

Public awareness

4.1 The first step to preparing for a disaster is awareness. Participants A, B, and C stated that there is generally a high level of public awareness of the CSZ and its related hazards but also that there should still be more public education. The experts' perception of public awareness could be skewed because s/he deals with this topic everyday, surrounded by people who are also involved in preparedness or seismology. All participants mentioned that the public awareness of the CSZ has dramatically increased in the last decade. Participant D and participant B both mentioned the article in the New Yorker, "The Really Big One" by Kathryn Shultz. This article received a lot of publicity when it came out in 2015. It alarmed people both in and outside of the Pacific Northwest about the CSZ megathrust earthquake. This got many people's attention and resulted in a higher level of awareness of this region's geohazards.

4.2 When Participant D was asked if the CSZ and its hazards were common knowledge in their local area, s/he said, "In terms of the public? I don't know. I really can't say, That's a good question. I think it's less known than California." As the only one out of the four who does not directly work with human preparation, it makes sense that s/he has the least knowledge about public awareness. The other three participants have all been involved in conducting informational meetings and preparedness workshops to the public. The participants believe that public awareness is high, which could be skewed based on their line of work. Many people may choose to attend these informational meetings because s/he already has an interest in geohazard mitigation. It is the residents that do not attend these meetings that are most likely unaware or uninterested in taking part in preparation measures. From these results, we can conclude that there is generally a high level of awareness of the geohazards involved with the CSZ. Public surveys would be beneficial to more accurately measure public awareness. Awareness is the first

step towards taking the necessary preparation measures. Therefore, it is important for governmental agencies and schools to continue educating local populations about these hazards.

What motivates people to prepare

5.1 Awareness itself does not usually motivate people to take preparation measures (Paton et al., 2005). Every participant, except participant D, discussed the psychology of what motivates individuals to prepare for a disaster. Participants A, B, and C's work involves educating the public on CSZ geohazards and persuading individuals to take preparation measures. They all have researched, and made their own observations on, what presentation techniques can motivate individuals to prepare. They all agree that fear is an ineffective way to trigger individuals to prepare as fear can cause people to want to ignore or procrastinate. Studies confirm that the use of fear-based messages can hinder one's decision to prepare for natural hazards (Jones 2013, Cvetkovic et al., 2019). Participant A and participant B described what they have found to be efficient in persuading people to prepare.

5.2 Participant A makes the point that California and Japan are much more prepared for high magnitude earthquakes than the Pacific Northwest because they both have experience with minor geohazards (e.g., low magnitude earthquakes, tremors). It is relevant to reflect on a New Zealand based study exploring how experience influences earthquake preparedness: direct experience with minor earthquakes is a strong motivator to prepare for a major one (Becker et al., 2017). It is hard to motivate people who have not been through a disaster. S/he states that the most efficient way is to imagine the situation after the quake and thinking how much better you will feel knowing your actions saved your family, neighbors, and pets. In fact, one study argues that animal guardianship alone can motivate disaster preparation measures as one has a moral obligation to protect and provide for their pet everyday and in a disaster situation (Thompson, 2015). Giving the individual the sense that they will be a hero to their loved ones, whether it's a pet, spouse, or neighbor, afterwards is a useful method of motivating disaster preparation.

5.3 Participant B believes that their community minded approach and message helps get people on board with preparation efforts. S/he states, "A lot of people have this armageddon... like everyone's going to be against each other after a natural disaster but I bring up the point that research has shown that by and large, people reach out to each other after a disaster. People's best selves come out so I try to reduce fear that way." In their lectures, s/he makes sure that s/he are realistic about the risks and what the area will face afterwards without deliberately scaring their audience. S/he tries to debunk the idea that everyone will turn against each other in the competition for resources by highlighting and promoting the help-your-neighbor ideology. It is similar to the founder of the infrastructure resiliency group's method in the sense that they both try to minimize fear and overwhelming their audience. Instead, s/he focuses on the benefits of preparing for disasters which are potentially saving yourself, your family, and your neighbors.

5.4 There are many published peer reviewed articles on what motivates people to take preparation measures for a natural disaster and the reasons why some aware individuals do not prepare. A study that explores the concept of denial in the decision to prepare for wildfires in Australia suggests that denial may be a reason for why some individuals do not prepare for natural hazards. However, it is concluded that more often, people do not put in the effort and money to mitigate natural hazards because demands of everyday life are a higher priority (McLennan et al., 2017). This is especially true for the lower to middle class as they may not have the time or money to spare for geohazard mitigation, making them more vulnerable in a disaster.

Community building

6.1 All of the participants mentioned that preparation is a community building task and when a high magnitude earthquake strikes, individuals will have to rely on their community. It was the second highest mentioned theme being mentioned a total of 18 times. Each participant highlighted a different way that communities are important when preparing for, experiencing, and recovering after the CSZ megathrust earthquake and tsunami. This section has some similarities with the previous section as being community oriented can motivate individual preparation measures. Participant C and participant B mentioned community the most as their careers require them to interact with community members on a regular basis.

6.2 Participant C made it clear how important your community will be after the earthquake. S/he describes the waiting period; the time after the earthquake in which people will have to provide for themselves with the resources available until aid or rescue arrives. Surviving the earthquake and tsunami is one thing but surviving the wait period could be equally as challenging. During this time, community members will need to rely on each other for resources. S/he explains that those who choose not to prepare will be a burden on the rest of the community as those who did prepare have to stretch their resources to accommodate those who did not. “We as the rest of the community need to over prepare in order to accommodate those individuals that don’t [prepare].” S/he is suggesting that it is irresponsible to be aware of this hazard and prepare. If everyone took some preparation measures, like having extra supplies of food, water, and emergency supplies, it will strengthen the community as a whole after the disaster takes place.

6.3 Participant B agrees that every individual that decided to prepare makes their whole community stronger when faced with the earthquake. However, s/he adds that making preparation measures benefits communities now. “This is about strengthening our community. This is about connecting. Preparedness is not only about making sure you have your supplies. Even if the earthquake doesn’t happen for 100 years, if you are connecting with your neighbors and talking to people about it, it makes the quality of your life better now.” When community members talk with each other and interact with the idea of a disaster, it can influence individual preparation measures (Becker et al., 2017). Preparing for disasters is a community building act

that not only makes more people more likely to survive in the face of a disaster but also connects neighbors and provides individuals with more peace of mind now.

6.4 Community-based disaster risk management (CBDRM) has become an increasingly used and studied approach to natural disaster mitigation since the 1980s (Lassa et al., 2018, Sarabia et al., 2020). CBDRM, also known as community-based disaster risk reduction and community-based disaster management, has been defined as an approach that enhances individual's capacity to cope with disasters and reduce vulnerability by reinforcing resilience at the local level, reduce human suffering, and accelerating the recovery process (Sarabia et al., 2020). Regarding the geohazards in the Pacific Northwest, CBDRM efforts include towns and counties having their own emergency plans such as tsunami evacuation routes and designated emergency shelters, community meetings to increase public awareness on geohazards and educating how to prepare on the individual and household level. Participant B regularly hosts public informational meetings on their county's geohazards. Informational meetings are about more than only spreading awareness, s/he establishes a relationship and promotes communication between community members and town officials about preparedness (Nakamura et al., 2017). Making connections and positive expectations towards individuals and local government in a community can enhance cohesiveness leading to a more resilient community (Peng et al., 2020, Becker et al., 2017). CBDRM is thoroughly integrated by local governments throughout the Pacific Northwest, however, the individual cooperation of all community members is necessary to make the whole stronger now and in the face of a disaster (Peng et al., 2020).

Cannot rely on government support

7.1 Another reason community is so important, particularly when thinking about this specific disaster, is the fact that after the earthquake there may be no local governments to rely on for help. There will be isolated communities that will be difficult for help to reach. Even if in areas that are accessible by outside help, the government does not have enough resources to provide food and water for the millions that may need it. The state government employee in our participant pool verified, "No, we absolutely do not have the capability or all of the resources to be able to respond to an event such as a magnitude 9 earthquake." However, s/he made it very clear that the state government has made an extensive effort in the last decade to educate the public on the local geohazards and has emergency response plans in place for a major earthquake tsunami event.

7.2 Participant A discussed how s/he believes that many people feel that s/he don't need to prepare because the state government is going to step in and rescue them. S/he said, "They don't realize that there will be no state government after it happens. There will be no officials getting

to work and no communication, no judiciary system, no health and human services... we can't count on the government. We will be back in the pioneer days."

Failing infrastructure and utilities

8.1 The theme that was mentioned the most is Failing Infrastructure and Utilities. It is closely connected to the Cannot Rely on Government Support theme as it is the government that is responsible for mandating seismic resistance building codes. These codes have only been introduced to the region in the early 1990s (Flynn et al., 1999). All participants are concerned that we will lose a great amount of infrastructure to severe shaking due to older buildings not being up to code. All of them also mentioned that soil liquefaction is a major concern. Two participants brought up concern for coastal towns as many essential buildings, like government buildings and hospitals are built in tsunami inundation zones. The lack of up to code buildings and the amount of infrastructure built on liquefiable soil and/or in tsunami inundation zones suggests that the Pacific Northwest will experience severe destruction when the fault slips and it is a main concern of all our participants. In 1999, a study proved a high level of public support for using state funds to increase infrastructure resiliency, especially buildings that aid in emergency response capabilities (Flynn et al., 1999). Since awareness had increased in the last two decades, it may be inferred that there is also increased support for making sure our infrastructure is seismically retrofitted.

8.2 Only recently have seismic infrastructures codes been introduced in the Pacific Northwest. As participant C explains, "We are still in the infancy stages in building infrastructure that will be able to withstand earthquakes. Even though our building codes went into place in 1990 for earthquakes, How many new governmental, business, industrial buildings have been rebuilt? Not many because it's expensive." S/he states that the government is making efforts when funds are available to make infrastructure more resilient, prioritizing public infrastructure, specifically roads. S/he closed their remarks on their county's infrastructure by saying, "Most of our public infrastructure will fail or will not be usable for many months."

8.3 Participant B painted a clear picture of what Eugene, Oregon will look like after a high magnitude earthquake. As the interview was conducted outside at a coffee shop in downtown Eugene, s/he pointed out all the buildings that have been built before seismic resistance regulations were mandated and will most likely collapse in an earthquake. It was almost all of them. S/he pointed out the utilities and services we will lose after an earthquake, "Over 50% of bridges in Oregon are expected to collapse. Railroad tracks will be vibrated off their beds, the airport is built on liquefiable ground so they'll be gone. Electric towers will collapse. As well as cell phone towers and internet relay towers. So we're looking at transportation, communication, and electricity all failing." After the next CSZ megathrust, communities will be isolated. This

enforces the idea that you cannot rely on government support after the quake, as there will be no governmental buildings left standing and no way to communicate between officials or to the public. With infrastructure and utilities failing, individuals will need to rely on themselves and their community to get the resources needed to survive.

8.4 S/he then went on to describe a very vulnerable population: students. In 2005, the State commissioned a seismic study of all the schools in Oregon. The completed report came out in 2007 and it is estimated that over 80% of schools will collapse during a high magnitude earthquake (Lewis et al, 2007). S/he said grimly, “If the earthquake happens during the school year, on a school day, we're going to have a lot of kids injured and killed.” Schools are also structures that could potentially provide shelter for a large number of people if s/he are built to withstand shaking. The State allocated money for schools to make improvements but the planning will not begin again until Spring 2020. Oregon also allocated money to improve their roads and bridges so that emergency services can actually reach people after the quake but it is a slow process. Along with failing infrastructure, schools are generally unprepared for a major disaster and this is not unique to this region. Students and universities being unprepared for disasters is common but there is a growing interest in academia in evaluating disaster preparedness procedures (Tkachuck, 2016). Hopefully, more research will result in an increase in schools preparedness and enhance student’s safety.

Other geohazards

9.1 All of the participants mentioned that when thinking about seismic disasters in the Pacific Northwest, it is necessary to consider all the geohazards, not only the CSZ megathrust earthquake. Participant D discussed how along with the CSZ, the Pacific Northwest has many other crustal faults and active volcanoes that are geohazards. This could play into motivating individuals to prepare for geohazards knowing that with more geohazards there is a higher probability that they will be affected by one in their lifetime. Participant C says, “Yes, the 9.0 is looming but Oregon also has many crustal earthquakes that could affect your property or house... it is really all earthquakes, all hazards that you need to be prepared for.”

Vulnerable Populations

Table 3. Participants A, B, and C, were asked, “**What are the most at risk areas or populations in your area?**” These are the summarizing quotes from their answer. Participant D was not asked this question due to their job category and s/he did not mention vulnerable populations.

	Summarizing Quote on Vulnerable Populations
Participant A	“So those are the four [vulnerable populations], the elderly, mentally and physically challenged, children, and pets.”
Participant B	“I think a lot about downtown Portland, downtown Seattle, highly and densely populated areas. And obviously the coast is super at risk for the tsunami after a Cascadia earthquake.”
Participant C	“The folks closer to the shoreline have a greater effect with the subduction zone earthquake because of the tsunami so we take more preparedness outreach activities to try to warn those community members that their impact will be greater.”
Participant D	Not applicable

10.1 Another topic discussed by three participants, except participant D, was the populations that are extra vulnerable to the region's geohazards. This theme was not calculated into the six themes previously identified and discussed due to the overlap in mentions and ideas. However, it should be emphasized as these populations are even more unprepared for a major earthquake event and will require more effort to mitigate hazards. Vulnerability can be defined as, “the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard” (Donner et al., 2011). Participants A, B, and C had discussed different vulnerable populations. Participant B and C focused more on population vulnerability as a result of location; coastal communities and densely populated cities. Participant A listed individuals that are vulnerable due to personal conditions.

10.2 Residents of coastal communities in Northern California, Oregon, Washington, and British Columbia are extremely vulnerable to geohazards of the CSZ. As participant B and C expressed, being located at the closest proximity to the fault, coastal communities will experience some of the most intense shaking (Cascadia Region Earthquake Workgroup, 2013). The shaking will likely be their only warning to evacuate in order to escape the following tsunami. It is predicted that after a CSZ earthquake, residents of coastal communities have 15-20 to evacuate before the tsunami makes landfall (Wood et al., 2015, Cascadia Region Earthquake Workgroup, 2013). During this time, roads may be damaged or blocked with debris and bridges may have collapsed making it difficult or impossible to flee to higher ground. Communities and individuals may be stranded until help arrives, this is why participant C directs their preparedness outreach efforts towards coastal communities. It is necessary for individuals living near the coast to take extra preparation measures to ensure survival during the next CSZ megathrust earthquake and tsunami event.

10.3 Participant A highlighted how personal conditions can make population groups vulnerable. For example, it is more difficult for people with disabilities to take mitigation measures, respond safely during an emergency event, and recover afterwards (Ballen, 2009). People that require assistance to walk will struggle to get to a safe location during and after the shaking. In coastal communities, individuals with restricted mobility may struggle to evacuate and escape the tsunami in time. Senior citizen homes and hospitals, especially those in the tsunami inundation zone, are at a very high level of risk due to their location and the varying degree of abilities of their inhabitants. Any person who is dependent on another will be of heightened risk. Along with mentally and physically disabled people and elders, children are vulnerable as they rely on their guardians. As discussed in the Failing Infrastructure and Utilities section, children are also at a very high risk if the earthquake occurs during the school day, as most schools are not seismically retrofitted. More research is needed to identify specific vulnerable populations in the Pacific Northwest as they will need the most immediate aid after an earthquake tsunami event. They may also be the most difficult for help to reach. It is necessary for these populations to take extra preparation measures in order to survive and recover.

Vulnerability and Environmental Justice

11.1 Disasters disproportionately affect people of low socio-economic status and people of color (Donner et al., 2011, Méndez et al., 2020). No participants directly mentioned this connection, however, it is an important point to include. The increased vulnerability of these populations is an environmental justice issue. Socio-economic status contributes to one's level of vulnerability as low income households are less likely to mitigate natural disasters and are less resilient after (Ballen, 2020). These community members may be struggling to meet the demands of everyday life, therefore, not have the resources to collect and store emergency supplies, repair homes and replace belongings, and support themselves during the recovery period (McLennan et al., 2017, Cascadia Region Earthquake Group, 2013). They also are more likely to live in older buildings that have not been seismically retrofitted. In the United States, minority groups generally have lower levels of income and are more likely to be impoverished when compared to the population as a whole (Donner et al., 2011). This is a racial justice issue that can contribute to higher levels of vulnerability to geohazards.

11.2 Natural disaster's disproportionate impacts reveal racial injustices. The people that immigrated to the Pacific Northwest may not be aware of the local geohazard, therefore, have taken no precautionary measures. The majority of recent immigrants in the area are from Mexico (American Immigration Council, 2020). Language barriers can hinder non-english speakers' understanding of disaster warnings and instructions during an emergency event, increasing their level of vulnerability (Donner et al., 2011). In 2016, the American Immigration Council predicted that 350,000 undocumented immigrants live in Washington and Oregon (American Immigration Council, 2020). This population will not receive the full extent of rescue and

recovery efforts. The Federal Emergency Management Agency does not offer its full range of disaster related assistance to undocumented immigrants, such as Disaster Unemployment Assistance (Federal Emergency Management Agency, 2020). They are also less likely to seek help because they risk deportation. A study aimed to understand the vulnerability of undocumented Latinx communities in regard to the Thomas Wildfire in Southern California. The results concluded that aid and resources were directed towards privileged individuals and the vulnerability of the Latinx population was derived from structural inequality (Méndez et al., 2020). It was suggested that future disaster management planning should give special consideration to minority groups, including undocumented citizens (Méndez et al., 2020).

11.3 In addition to race and socio-economic factors, gender can play a role in determining one’s level of vulnerability. Studies agree that women are more vulnerable due to their traditional gender roles as protectors, planners, caregivers to the young and old. They are most likely to be responsible for someone else and have to go out of their way to save their dependents, often putting themselves in harm's way and having to deal with excess psychological trauma (Peng et al., 2020, Donner et al., 2011, Ballen, 2009).

11.4 People of low socio-economic status, people of color, and women deserve special consideration regarding preparation for geohazards related to the CSZ. Extra measures must be taken on the individual, community, and governmental level to protect these vulnerable populations in the face of a disaster. Further research into how we can increase safety and resilience in these populations would be beneficial.

Summarizing quotes from each of participant

Table 4. A quote was selected from each participant that summarizes their perception of risk and/or level of preparedness.

	Job Title	Summarizing Quote
Participant A	Founder of a preparation group that specializes in infrastructure resilience in Oregon	[When asked how individuals could best prepare themselves] “Move elsewhere. I’m serious.”
Participant B	Founder of a small business that sells post earthquake supply kits to increase individual and community preparation	“This is about strengthening our community.”
Participant C	County emergency manager for a coastal county in Oregon	“We have culturally accepted that the hazard exists, that we have responsibilities at the individual, family, business, state, federal, local...everybody finally accepts that they own part of this.”
Participant D	Research professor in the Seismology Department at a large university in Seattle, Washington and manager of seismic network, tracking all seismic activity in the Pacific Northwest	[When asked how individuals could best prepare themselves] “It’s an individual choice. I’m not sure I would because I don’t think it’s necessarily valuable given the structure of my life. It’s a complicated issue, you know, it’s all just gambling.”

Experts risk perception

12.1 Participant A and participant D perceive risk very differently, which is why they have such contrasting opinions on whether it is necessary to prepare for this event or not. Participant D said, “Based on geological evidence, we would say that there is about a 15% chance, in any 50 year period, of a large megathrust.” If there is only a 15% chance of something happening in your lifetime, maybe that is not a high enough percentage to motivate preparation. If the odds were 85% in your favor, would you “gamble” with those odds? Perhaps because on paper, it seems low risk. Participant A presented the odds a very different way. “Risk is usually assessed by probability and seriousness. So, the probability that the earthquake will occur is 100%, the seriousness on a 1 to 10 scale is a 10. That is the highest level of risk you can get.” Their level of risk perception is why s/he has an eight-month supply of food for their family, three-month supply for their pets, and a seismically retrofitted home.

Conclusions

13.1 The CSZ megathrust earthquake is looming over the Pacific Northwest. It is not a matter of if, but when. The participants agree that there is a high level of public awareness on this event, however, awareness does not equate to preparedness. There still needs to be more public education on geohazards to continue to raise public awareness but also to educate community members why it is important to take preparation measures. Why some people are motivated to prepare and others don't may have to do with the way they perceive risk. It is also possible that individuals do not prepare because they do not have the financial or physical means to prepare. Low-income communities, people of color, and women require special consideration in order to increase preparation and resiliency after the earthquake as disasters disproportionately affect these populations. When trying to motivate people to prepare for a natural disaster, you must not use fear but instead ask them to picture themselves in a situation after an earthquake looking back, knowing their preparation actions saved themselves, their family, and their community. Surviving after this earthquake will be a community effort so preparing should be a community effort as well. For those that do not prepare on the individual level can be a burden on their community later. The government must prioritize actions that help make their infrastructure and utilities more likely to survive the earthquake and tsunami. It could mean the difference of life and death for building patrons as well as communities that will be isolated from each other. In order to make the Pacific Northwest more resilient in the face of the next CSZ megathrust earthquake, it is necessary to take more preparation measures on the governmental, community, and individual level.

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