

FIELD MEASUREMENTS OF TSUNAMI EVACUATION DYNAMICS

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RESEARCH NEEDS

The Cascadia Subduction Zone (CSZ) threatens Vancouver Island, Canada, with a significant risk of near-field tsunamis. Both oral history and geological records (Ludwin et al., 2005) document the last major CSZ tsunami event in the year 1700. To mitigate the loss of life during tsunami events, soft measures, such as evacuation planning, have been suggested (Shibayama et al., 2013). Considering that Vancouver Island is expected to face wave arrival times within 20 minutes for a CSZ tsunami (Takabatake et al., 2019), detailed and accurate evacuation planning is essential. Agent-based models (ABMs) have been recommended in preference to Geographic Information Systems (GIS) when performing evacuation assessments as they can portray evacuation dynamics more realistically (Kim et al., 2022). While tsunami evacuation ABMs have been used to assess life safety for multiple coastal communities (Mas et al., 2015), there is a significant lack of data on tsunami evacuation behaviour to inform and calibrate these ABMs.

OBJECTIVES AND NOVELTY

Overarchingly, this study aims to evaluate tsunami evacuation preparedness in the District of Ucluelet, British Columbia, Canada. More specifically, it establishes the first tsunami evacuation ABM calibration dataset available worldwide and at the level of individual evacuees. This is the first study that utilizes agent tracking using individual GPS devices combined with questionnaire/survey outcomes to quantify tsunami evacuation dynamics, where the study population is composed of general public volunteers.

METHODOLOGY

A tsunami evacuation drill for the District of Ucluelet was conducted on April 15th, 2023 (Figure 1). Participants, comprising both local residents and tourists, initially completed a paper-based questionnaire on their socio-demographic characteristics and comprehension of tsunami hazards prior to the actual evacuation drill. Before the drill, participants were allowed to review Ucluelet's tsunami hazard map. Each participant was equipped with a box containing a NEO-6M GPS module built by the authors to track their movement throughout the evacuation drill. The GPS module has a specified horizontal accuracy of 2.5m. Participants freely chose their start locations (i.e., where they believed they might be during a tsunami) and evacuated by whichever mode of transportation they deemed most realistic for them until they felt safe from any tsunami hazards (Figure 2). This was also a way to test the individual level of knowledge of the tsunami hazard

inundation boundaries. No additional wayfinding was introduced to guide the participants during the drill. The start of the evacuation drill was signalled via the community's emergency notification system.

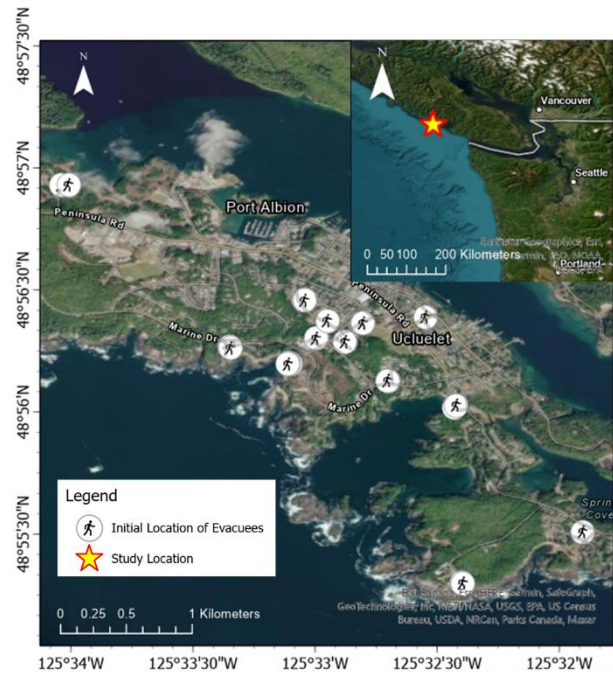


Figure 1: The study was held in the District of Ucluelet on Canada's Pacific coast. The spatial distribution of the initial location of evacuees during the tsunami evacuation drill is displayed.



Figure 2: A group of four pedestrian evacuees on a gravel trail. The evacuation drill was held during a "Rainfall Warning" issued by the local weather station.

RESULTS

The evacuation drill was held at 15:00 local time and was attended by twenty-seven unique individuals. The mean temperature during the evacuation drill was 7°C, and a rather intense total rainfall of 57 mm was recorded for that day.

Participant Demographics

The age range of participants was between 9 years and 77 years old, with a mean age of 44 years and standard deviation of 19 years. 63% were female, 33% male, and 4% undisclosed. A share of 85% of participants were residents, while the remaining 15% were visitors.

Tsunami Hazard Awareness

All participants knew what a tsunami was. Notably, 30% of participants could not identify if their residence is in danger of flooding from a tsunami, hinting at the existing potential for additional educational activities to further improve preparedness and risk mitigation. Of that 30%, one-fourth were visitors, with the remainder being residents.

Tsunami Evacuation Preparedness

For 56% of participants, this was their first tsunami evacuation drill. Participants were asked to estimate how long it would take them to evacuate from their residence to what they deemed/knew to be a safe location. 62% of participants underestimated their evacuation duration (i.e., they thought they could complete the evacuation in a shorter time than required). 64% of participants estimated they would need more than 5 minutes of preparation time before starting their evacuation, 82% of participants responded that they would seek out their children, family, pets, and/or friends before evacuating. **However, this additional time was not reflected in the participants' estimate of evacuation preparation time or duration, implying that actual evacuations may take considerably longer.**

Spatial Tracking of Evacuees

82% of participants evacuated on foot, while the remainder evacuated by vehicle. Figure 3 shows the recorded walking speed and elevation gain of a 10-year-old female participant. The corresponding evacuation route recorded by the NEO-6M GPS module can be seen in Figure 4. It is important to note that the GPS tracking allowed a correlation between the travelled elevation profile and speed of evacuation as a time-history; such information was not previously unavailable to modellers and enables

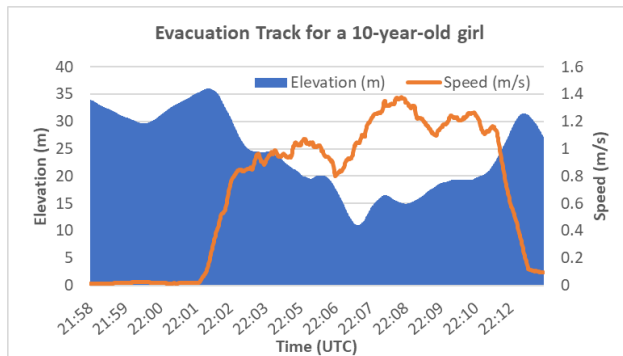


Figure 3: Walking speed and elevation recorded by the GPS device for a 10-year-old participant.



Figure 4: The GPS coordinates and UTC time recorded during the tsunami evacuation by the NEO-6M module for a 10-year-old girl (Participant ID #45).

The average pedestrian evacuation speed for all participants was 1.3 m/s with a standard deviation of 0.7 m/s. Further investigation of the relationship between walking speed, terrain, and demographic profile and using evacuee tracks for calibration in tsunami evacuation agent-based models is underway.

CONCLUSIONS

Tsunami evacuation dynamics at the District of Ucluelet were measured by combining GPS tracking and questionnaires to produce the world's first tsunami evacuation ABM calibration dataset. The dataset was used to assess Ucluelet's level of tsunami evacuation preparedness. Notably, it was found that the majority of participants underestimated their evacuation duration, emphasizing the urgent need for enhanced educational outreach and evacuation preparedness.

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