Crowdsourcing tsunami observations in Aotearoa following the Hunga Tonga-Hunga Ha'apai eruption

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In December 2021 the Hunga Tonga-Hunga Ha'Apai (HTHH) caldera volcano in the Kingdom of Tonga, approximately 2000 km north-east of Aotearoa, awoke. On January 15 2022, after a period of unrest, a large eruption produced ash plumes and generated tsunami and shock waves, which were experienced globally.

In Aotearoa, a National Advisory for Tsunami Activity was activated from 8.14 pm on Saturday 15 January to 7.06 pm on Sunday 16 January 2022 (NEMA, 2022). GNS Science activated its internal coordinated incident management system (CIMS) focusing on monitoring tsunami threats, understanding tsunami propagation, and calculating impact assessments both nationally and in Tonga. Instrument records such as tidal gauges and DART (Deep-ocean Assessment and Reporting of Tsunamis) buoys recorded physical processes such as wave height and arrival time, but lacked insights into how communities were impacted. To address this, an interdisciplinary team of social, volcano, and tsunami scientists deployed an online survey to the New Zealand public between January 21st and February 13th, 2022.

Our survey was advertised through a GeoNet website news story, social media posts (on GeoNet Facebook and Twitter) and a television interview. Through the SurveyMonkey web survey we received 2072 observations, and through a GNS Science email address we captured a further 30 observations.

In total 17 images and videos were sourced. From the 39 questions, 10 focused specifically on people's experiences at the coast and observations of potential tsunami activity. Using the limited location information provided we geolocated 163 tsunami observations (of 295 total). For each quantitative question summary statistics were produced (minimum, mean, median, maximum, standard deviation), and aggregates based on location were calculated at regional authority and postcode scales.

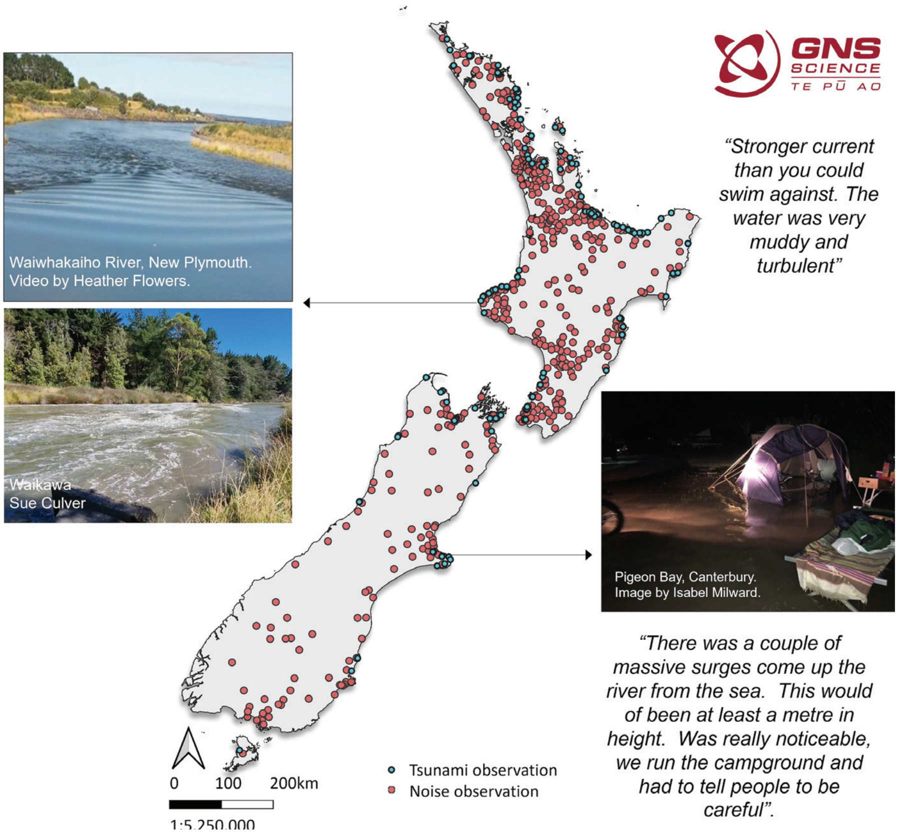


Figure 1: Location of crowdsourced observations following the January 15 2022, HTHH eruption with example responses/images from the public.

We conducted thematic analysis of free text to identify common topics, impacts noticed, details of physical changes (such as water colour/height), and people's responses.

Survey results

Participants who observed unusual sea conditions often saw unusual surges of water approaching or retreating the shore. Some observed impacts on the natural or built environment that they believe were caused by water movement.

The four closest New Zealand DART Buoys (NZ: A, B, C, D) located off the East Coast first recorded peaks in sea level between 2.8 cm and 3.7 cm arriving from ~7.43 pm to 8.13 pm NZDT (Gusman and Rodgers, 2022). The first credible crowdsourced reports observed changes in the late evening on the day of the eruption. Early reports were predominantly on the East Coast, as indicated by yellow stars in Figure 2, with most observations noting changes the following day.

When asked to describe changing currents and wave activity many respondents noted stronger than expected movement, unusual and unpredictable tides that were higher or lower than expected, and which did not align with expected tide levels. Furthermore, rather than a singular tsunami wave, multiple surges were witnessed, aligning with evidence from instrument records that often the waves arrive in sets. Many individuals reported a sudden drop or increase in water level, sometimes catching them off guard.

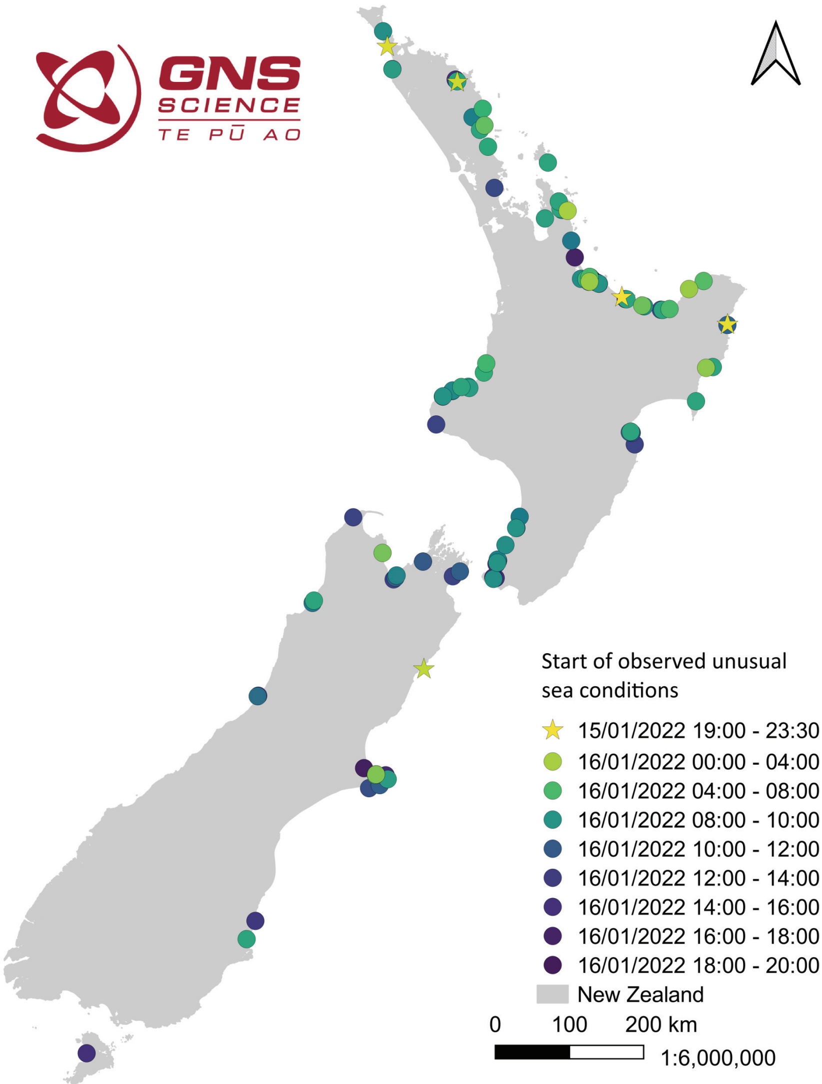
1. Did you notice any unusual sea conditions on 15 or 16th January 2022?
2. Location (Region, post code, town street or location)?
3. Start and end Date/Time (observing the sea, and observing unusual conditions)?
4. Did you notice unusual surges of water, either approaching the shore or retreating from the shore)?
   a. *If yes, how many surges did you notice, and how long did each last?*
5. Did you notice unusual changes in the water level or currents?
   a. *If yes, please estimate the change in water level between its highest and lowest points or describe the change in currents.*
6. Did you observe unusual colours or other appearances of the sea?
   a. *If yes, what did you notice?*
7. Were there any unusual sounds or smells associated with the sea?
   a. *If yes, what were the sounds and/or smells?*
8. Did you observe any impacts on the natural or built environment that were caused by the water movement?
   a. *If yes, what were they?*
9. If there are any other details you think it would be useful for us to know about the tsunami, please state them here.
10. Do you have any photos of the sea showing unusual behaviour, or of damage in coastal areas?

Table 1: Tsunami observation survey questions.

For example:

> *'There was a couple of massive surges come up the river from the sea. This would of been at least a metre in height. Was really noticeable we run the campground and had to tell people to be careful.' [sic]*

> *'We were fishing you were standing ankle deep then a surge would come in and you would be waist deep and retreating to shore. The shoreline was moving about 25 meters with a surge. Never seen anything like it.' [sic]*



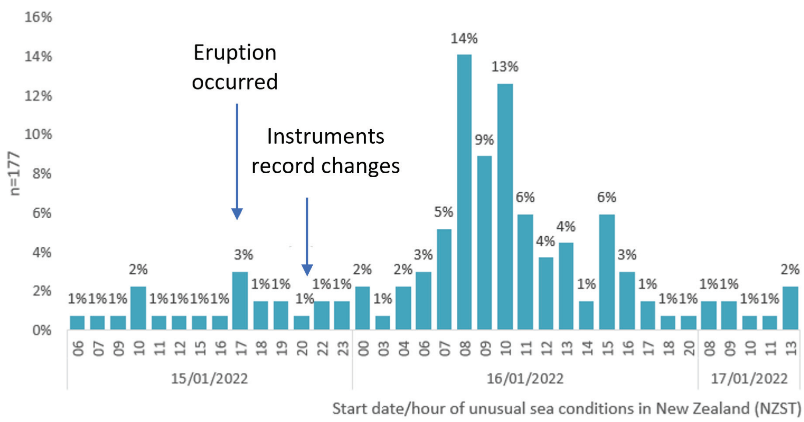


Figure 2: Start date and time of unusual water conditions, 15/16 January 2022.

Surges were witnessed at coastal beaches and inland rivers and streams, with images and text describing murkier, sediment-laden discoloured water.

Discussion

Crowdsourced data can build situational awareness for response agencies, identify impacts on the built and natural environments, provide insights into behavioral response to hazardous events, and fill gaps in the sensor networks. Following the HTHH tsunami activity, reports of damage at Tutukākā Marina were widely publicised. Our survey identified other impacted locations, such as flooded campgrounds in

Canterbury, and debris on roadways that may not be captured by other means. Our thematic analysis identified issues with delayed or missing tsunami warnings, and gave insights into the public's perceptions and experiences, made possible through social science survey methods.

There are, however, challenges with using crowdsourced data. In this case study, it was difficult for the public to differentiate between tsunami activity generated during the HTHH eruption, and ongoing surges from ex-tropical cyclone Cody. Misreporting, such as respondents reporting unusual sea conditions prior to the eruption occurring, was evident. Regardless, the public were highly engaged and willing to participate with over 1500 respondents willing to engage in follow up activities, including talking to a scientist.

Future work

This survey was created rapidly during the HTHH event response. We later identified some issues such as limited geolocation functionality. To overcome issues, increase the efficiency and repeatability, and to hasten dissemination of results to stakeholders and emergency response agencies, GNS science are redesigning the tsunami survey. We are engaging in expert elicitations, developing, and testing online data sharing portals, and exploring interactive public web visualisations using a new cloud-based platform.

Acknowledgements

Thank you to our respondents for taking the time to provide their insights, images and videos. Full results will be made available in a GNS Science Report (in prep.).

Figure 3: Descriptions of unusual colour or appearances.

Project team

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References

Gusman, AR and Roger, J (2022). *Hunga Tonga - Hunga Ha'apai volcano-induced sea level oscillations and tsunami simulations*. GNS Science webpage accessed Feb 2022 at: https://www.gns.cri.nz/news/hunga-tonga-hunga-haapai-volcano-induced-sea-level-oscillations-and-tsunami-simulations/

National Emergency Management Agency [NEMA] (2022). *DART network proves invaluable in assessing tsunami threat following the Hunga Tonga-Hunga Ha'apai eruption*. Webpage accessed 02/08/22 at: https://www.civildefence.govt.nz/resources/news-and-events/news/dart-network-proves-invaluable-in-assessing-tsunami-threat-following-the-hunga-tonga-hunga-haapai-eruption/

View of Nomuka, Tonga from an RNZAF flight two days after the 15 January 2022 volcanic eruption (Photo: New Zealand Defence Force).