Disaster cultures and the Indonesia Tsunami Early Warning System: (mis) alignments revealed by the 2018 non-tectonic tsunami in Labuan

Abstract

This study examined the (mis) alignments between multiple disaster cultures, the Indonesia Tsunami Early Warning System (InaTEWS) and local risk profiles as revealed by the 2018 non-tectonic tsunami triggered by the Anak Krakatau Volcanic eruption in Labuan. The research assessed to what extent the tsunami warning system was adapted to local needs and characteristics. Based on qualitative data collection, this study showed that before the 2018 tsunami (and notwithstanding memories of the 1883 Krakatau tsunami) different local groups shared a strikingly homogeneous understanding of tsunamis as exclusively triggered by earthquakes. After the 2018 tsunami, study participants reported increased awareness of different tsunami types and earthquake risks. However, this rarely translated into practical actions and changes at the local level as structural and cultural factors significantly hampered the work of local government and emergency management agencies. This research identified steps to improve alignment, for example by involving community members in warning technology maintenance, tailoring awareness-raising materials to local hazard profiles and connecting awareness-raising with local cultural traditions. However, a reform of the InaTEWS is necessary, including overcoming sectoral silos and incorporating local knowledge and experiences into policymaking. By addressing these (mis)alignments, authorities can better support communities to understand tsunami risks and respond to future event, ultimately enhancing preparedness.

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Introduction

On Saturday night, 22 December 2018, a series of tsunami waves 'silently' hit the coastal areas of Banten and Lampung provinces surrounding the Sunda Strait of Indonesia. According to the Indonesian National Disaster Management Authority (BNPB) (2018), Labuan district of Pandeglang Regency, Banten (Figure 1), was one of the most affected in relation to casualties, infrastructure and economic consequences. The government initially referred to the event as an 'extreme tidal wave' but later confirmed a tsunami that was likely the result of a partial flank collapse of the Anak Krakatau Volcano situated between the islands of Java and Sumatra (Ye *et al.* 2020; Zengaffinen *et al.* 2020). The local communities of Banten and Lampung provinces did not experience any prior earthquakes nor receive any warnings from authorities. While the Indonesia Tsunami Early Warning System (InaTEWS) has been operational since 2008, it was designed to produce tsunami warnings based on seismic events only (Annunziato, Prasetya and Husrin 2019; Titov 2021).

The 2018 tsunami underlines the need to align tsunami warning systems with local needs and characteristics. This is true in terms of risk profiles as tsunami can be triggered by earthquakes, volcanic eruptions or submarine landslides as researched in Indonesia and Australia (Brune *et al.* 2010; Paris *et al.* 2014; Puga-Bernabéu *et al.* 2017; Clarke *et al.* 2019). That alignment is also necessary in terms of disaster cultures. Cultural beliefs, customs and practices play a significant role in disaster risk reduction (Bankoff *et al.* 2015) and must be incorporated into risk planning, communication and warnings (Bankoff 2004).

Understanding how people perceive, experience and respond to emergencies reveals why they do or do not take action to minimise risks. Within government agencies, they constitute social groups with established customs and practices over time, shaping their approach to managing risks and disasters (Tierney 2007).
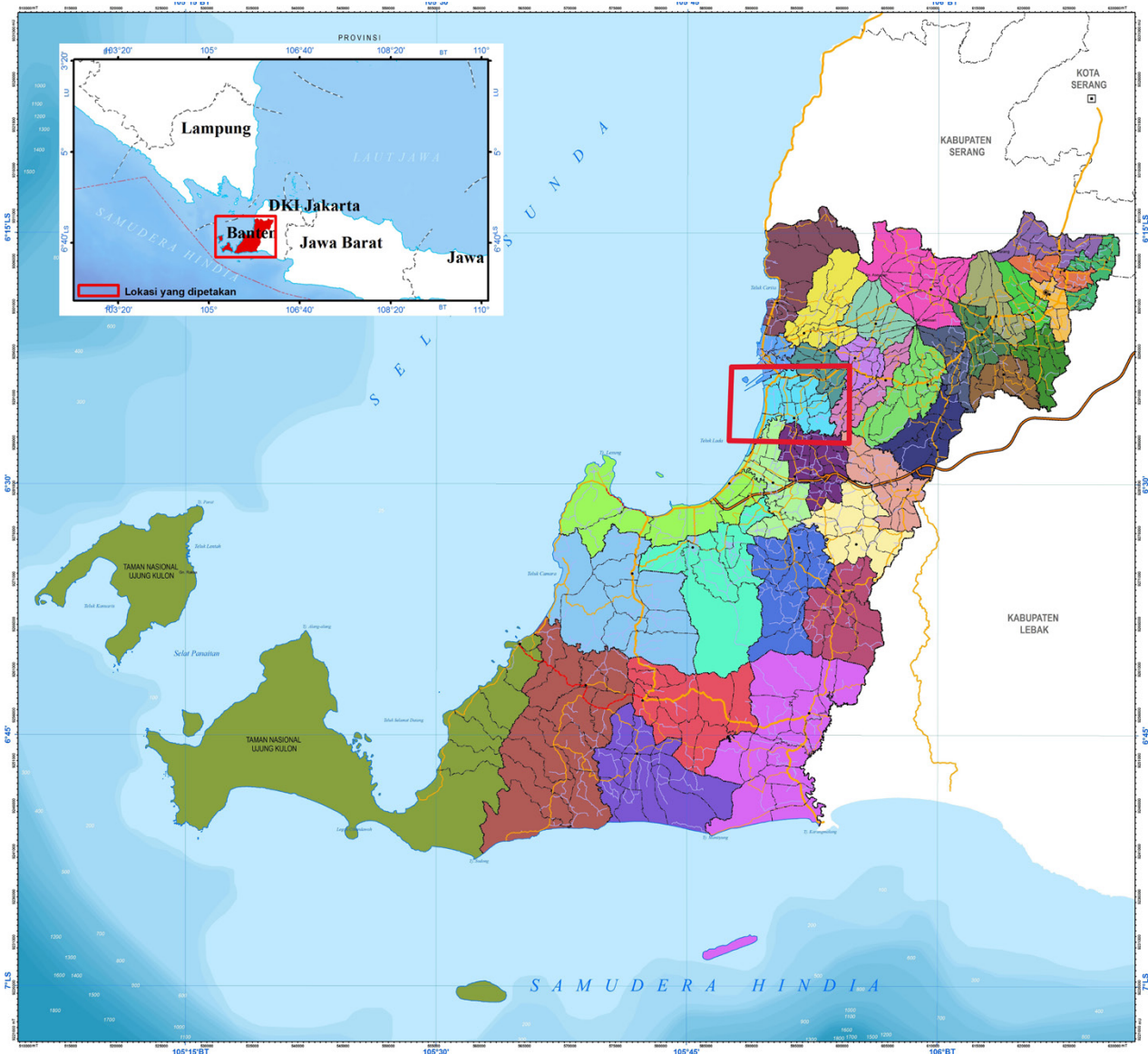
Figure 1: Locus of the study in Labuan district (red square) in an administrative map of Pandeglang Regency.

Source: Kabupaten Pandeglang (2011)

Figure 2 illustrates a triangle approach to analyse the alignment of local hazard profiles, multiple cultures and the InaTEWS instrumentation and procedures in the Labuan district.
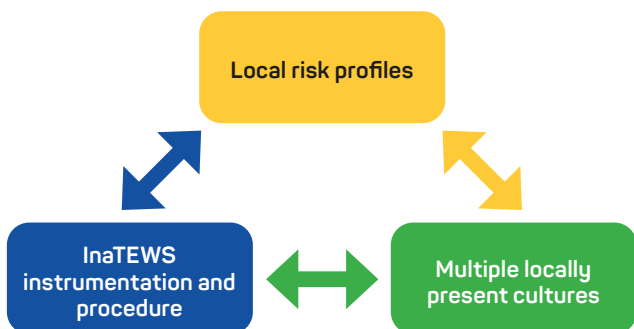

Figure 2: A model to analyse risk profiles, local cultures and InaTEWS systems.

Methods

Primary qualitative data were gathered between February and March 2023 and secondary data such as preparedness policies and reports were also reviewed. Semi-structured, in-depth interviews and focus group discussions were conducted with 72 participants from local community referred by snowball sampling and government agency officials selected through purposive sampling.

The community group included 37 residents from Teluk and surrounding villages. This included citizens active within the disaster risk reduction forum as disaster preparedness village representatives or Balawista lifeguards. The government group comprised 35 officials who worked in the Labuan district office, the local disaster management agency, Anak Krakatau Volcano watch post or the Indonesian Meteorological Agency and BNPB.

Interview questions concerned participant experiences of the 2018 tsunami and included who they expected to provide warnings and call for evacuation as well as any improvements they would recommend.

Data analysis followed Stake's (1995) 3-stage approach: categorising data, identifying correspondences and patterns and developing naturalistic generalisations. A deductive (research question-driven) and inductive (data-driven) approach was combined using the atlas.ti software. Results aim to support analytical generalisation on the (mis)alignment of the InaTEWS with disaster cultures and their effect on preparedness.

Ethics approval was obtained from the National Research and Innovation Agency (BRIN), # 04012023000010, 26 January 2023.

Results

The analysis highlighted that although participant insights had considerably evolved since the 2018 tsunami, warning practices had not necessarily. Findings are outlined following 3 temporal phases of (1) before the 2018 tsunami, (2) what the 2018 tsunami revealed and (3) lessons learnt and applied following the 2018 tsunami.

Before the 2018 tsunami

Fieldwork revealed that the 1883 Krakatau eruption-induced tsunami shaped people's memories and practices. Research participants from the community group identified toponyms that indicate the tsunami landing sites, including the Longok neighbourhood in Sindang Laut village (meaning 'seawater that stops by') and Belangkas hill road situated 6 kms from the coast and named after the 'horseshoe crabs' found in Bojong Canar village (personal interviews, February 2023). Like toponyms, oral traditions passed on over generations serve as reminders of the 1883 tsunami. Some community members referred to tsunami as *Caah Laut* (flood from the sea) or *Kalembak* (rolled by waves), although these terms are being replaced by the better-known term 'tsunami'. Few families shared stories of the 1883 Krakatau eruptions, portraying the volcano as an evil entity luring people to the sea. However, this was limited and did not concern other people recently migrating into the area.

Regarding traditions, the 1883 tsunami gave rise to *Haul Kalembak,* an annual commemoration held by descendants to remember family members lost to the tsunami. Some participants viewed the event as a spiritual necessity, but suggested it should also serve as an opportunity to disseminate preparedness messages to communities. The same applies to the *Ruwatan Laut* or *Nadran,* a sea purification ritual created through the hundreds of acculturations of Islamic and Hindu cultures in Pandeglang. Fishing communities still carry out the ceremony under private sponsorship, leaving some to criticise the ritual as a tourist event.

Despite the memories and traditions linked to the 1883 eruption, community participants regarded the Anak Krakatau eruption as a beautiful attraction benefiting the local economy. Fishers shared how they did not perceive the volcano as a threat to be worried about as they were used to mooring their boats on the volcano island and waking up the next morning to find their boats covered in volcanic ash.

Before 2018, all community group participants indicated an understanding of tsunami as preceded by an earthquake, as they had been taught on television. This aligns with the earthquake-centred tsunami communication established by government agencies between the Meteorological, Climatological and Geophysics Agency (BMKG), BNPB and the Volcanology Agency. While Pandeglang Regency published a disaster risk assessment document in 2013 following the risk assessment guidelines issued by BNPB (2012), neither the guidelines nor the risk assessment document (see examples at Figure 3) considered non-tectonic tsunami origins.

Most community participants said they did not believe another tsunami would hit their area. They considered the installation of tsunami evacuation signs in 2012 and 2015 useless. Scepticism towards the local government and other emergency management practitioners was commonly expressed through statements such as: 'you are scaring people', 'life is God's business' and '[a] tsunami is just some news on television' (personal interviews, February 2023). A Balawista lifeguard offered another perspective and criticised the Local Disaster Management Authority (BPBD) of Pandeglang for installing signs using 'threatening wording' without consulting the community.

What the 2018 tsunami revealed

The 2018 tsunami highlighted how strongly disaster cultures centred on earthquake-centred tsunami. This earthquake-centred disaster culture extends to community perceptions of risk, the roles and responsibilities of agencies, the national choices of monitoring instrumentation as well as warning procedures.

Interviews with community members and focus group discussions revealed that villagers heard and felt the sound and tremors from the Anak Krakatau Volcano eruption in 2018. They were used to these since childhood, even though the tremors felt stronger and longer on 22 December. The natural signs did not warn the community and some villagers witnessed the arrival of the tsunami waves firsthand only later. As shared by one participant, a wave 3–4 metres high with foam 'white and long, like a group of ducks swimming in the middle of the sea' was visible from afar accompanied by a thunderous train-like sound and a gust of wind. Community members and government officials attributed the chaotic situation to confusing the tsunami for an extreme tidal wave. Communities had been repeatedly taught through training, socialisation and television news that an earthquake must precede a tsunami. One community member referred to this as 'patented', thus infallible wisdom.

According to observers at the Anak Krakatau observation post (9 February 2023), the volcano continuously increased its activity in June 2018. Its status was ranked based on a ministerial guideline (Kementerian ESDM 2011) at 'beware' or level II and was not changed to level III or IV (i.e. 'likely eruption') because the volcano is situated in the middle of the sea and 'it is far from the community, there was no need to evacuate anyone'. The Volcanology Agency only considers areas that can be affected by ash, sand, hot clouds, volcanic bombs
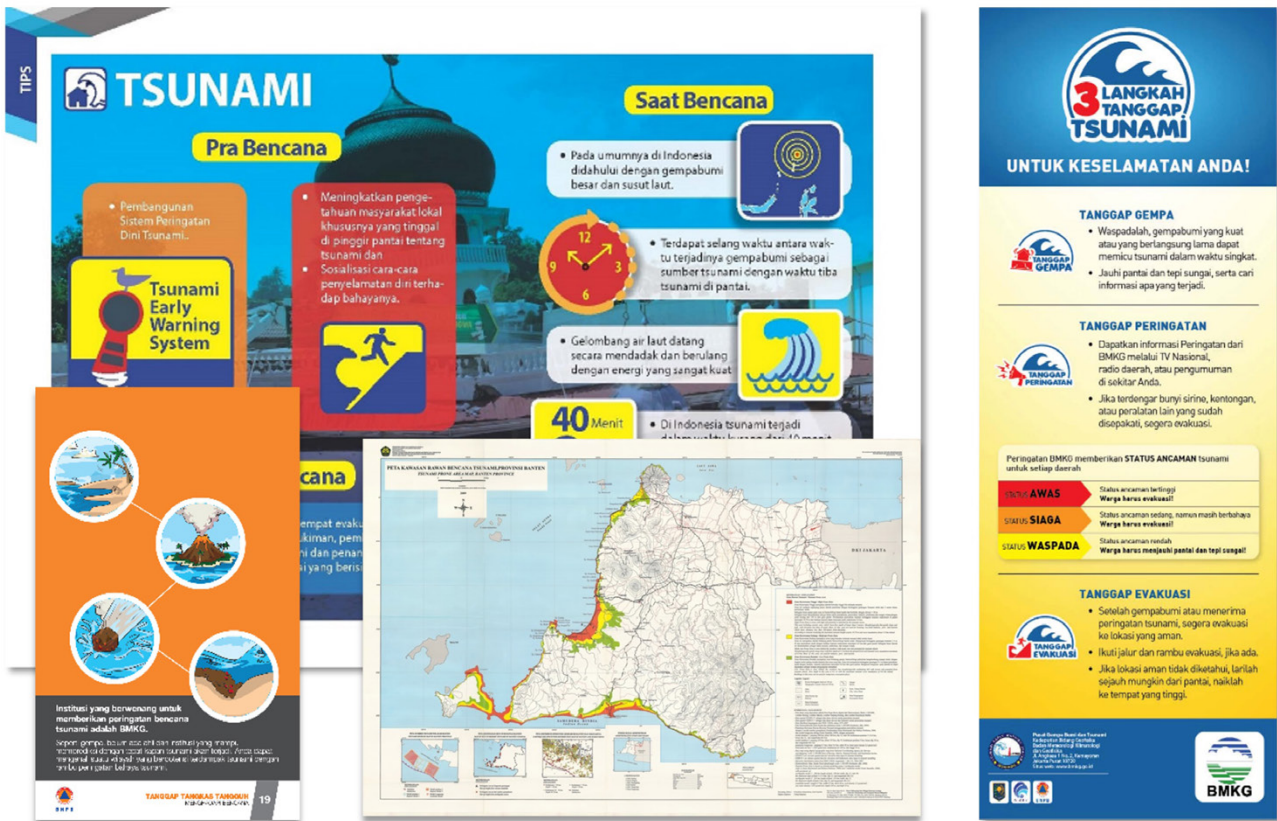
Figure 3: Examples of community tsunami preparedness materials.
Source: Volcanology Agency (2009); BNPB (2019b, 2019a); BMKG and IOTIC IOC UNESCO (n.d)

or lava flows within a 5 km radius. This may suit continental regions but is not sufficient for volcanoes at sea or in coastal areas where a tsunami may follow. Likewise, the 2018 tsunami was detected by several sea-level measuring devices installed by the Geospatial Agency along the coast but detection was too late for warning communities (Muhari *et al.* 2019).

Community and local government officials viewed BMKG as the authorised and trusted agency to provide official statements regarding earthquake and tsunami events. At the local level, BPBD Pandeglang officials considered themselves as mere users of early warning services in that they follow and relay information, warnings and statements received from the national BMKG, BNPB offices and the Volcanology Agency, and their provincial government. This partially aligns with the BPBD mandate in Presidential Regulation 93/2019, including providing information on disaster-prone areas, communication and education and a 24/7 warning dissemination service.

BMKG installed 2 tsunami sirens before the 2018 tsunami, each with a 0.5–1 km radius on the 307 km coastline of Pandeglang Regency. This was insufficient. Moreover the sirens were only periodically tested during trainings and were not activated on the night of 22 December 2018 (Borrero *et al.* 2020). Community members approved sirens as a warning method, yet these are controlled by the provincial BPBD and national BMKG, not by the local BPBD Pandeglang office. BPBD Pandeglang thus relies on WhatsApp, communication radio and loudspeakers to disseminate warnings and instructions to the community.

Post-2018

Following the 2018 tsunami, research participants reported a significant shift in their tsunami threat perception. This was reflected in increased acceptance of preparedness information. During fieldwork, community members living near the tsunami siren installed in Teluk village explained that the siren functions as a warning only in the event of a tsunami triggered by an earthquake. They also emphasised the distinctive features of their region, highlighting that the siren does not alert for non-tectonic tsunamis, which are considered a real threat. Interestingly, participants had become sensitive and responsive to earthquakes – a fact made visible through self-evacuation following the 2018 tsunami. This practice is not common in Indonesia, where residents often wait for top-down instructions before taking actions and evacuating.

The Pandeglang local government improved its spatial planning document by considering tsunami threats in zoning. Numerous institutions and organisations provided support between 2019 and 2022 to prepare a Disaster Emergency Response Plan, a Flood Disaster Contingency Plan and to form a Disaster Risk Reduction Forum to foster information sharing and to improve disaster management. The forum comprises practitioners, academics, government entities, members from the private sector and the media. Pandeglang government upgraded the classification of BPBD from Type B to Type A, which should provide additional budget. However, community members and

BPBD officials have not experienced much change (personal interviews, February 2023). Preparedness activities still do not consider the threat of non-tectonic tsunami and BPBD Pandeglang has not yet established agreements for tsunami warnings and quick reaction procedures. Government participants did not consider traditions such as *Haul Kalembak* worthy to tap into to improve community awareness.

In terms of technology, various warning devices were installed by BMKG, BNPB and the Volcanology Agency. However, BPBD and community representatives said their groups had not been involved in the process. This raises concerns about maintenance and continued functionality of introduced technologies. In contrast, sea surface monitoring devices were installed by BRIN using an approach involving fishers and water tour guides to help maintain the devices and some are trained to access data and perform simple troubleshooting (BRIN official, personal communication November 2022).

Several local and national disaster management officials described the 2018 tsunami as a wake-up call to develop a tsunami warning system that can detect non-tectonic tsunami sources. They emphasised the importance of aligning agencies in terms of policy, technical equipment and data gathering and use. Tangibly, the Anak Krakatau observation post now conveys major observation changes to BPBD Pandeglang, the BMKG Tsunami Warning Centre and other agencies through WhatsApp groups. Previously, and as per-procedure, the information was only sent to the Volcanology Agency central office in Bandung. Despite efforts to enhance integration, obstacles arose and BMKG and the Volcanology Agency developed joint standard operating procedures. However, challenges emerged due to disparities in metadata, skills and incompatible monitoring equipment, hindering further integration. According to a BMKG official (December 2022), '[w]e could not use the data from Anak Krakatau itself because there was much noise from the volcano, and we had difficulty analysing the tectonics'. BMKG and Volcanology Agency officials have discussed alternative non-tectonic monitoring scenarios. This includes observation and warning decisions based on the morphology and characteristics of volcanic eruptions, volcanic activity status and the influence of meteorological conditions that may trigger a tsunami. However, these are still in the discussion and (international) research stage.

Discussion

Results are considered from 3 perspectives: multiple disaster cultures, InaTEWS procedures and the local risk profile. For multiple disaster cultures, before the 2018 tsunami, there was a similarity in perceptions across community groups (e.g. recent migrants or people long involved in associations), local government and emergency management agencies. These groups primarily associated tsunami as being exclusively triggered by earthquakes and considered Anak Krakatau as non-threatening (although some agencies gave higher importance to tsunami preparedness). Despite memories of the 1883 non-tectonic tsunami as reflected in toponyms, local traditions and family stories, community members, particularly fishers, used the volcano island as a mooring spot and incorporated the volcano

into their daily lives. Likewise, the Volcanology Agency did not consider the volcano as a potential tsunami source and other agencies did not consider Anak Krakatau in their mandates.

Factors that may explain this include the tourist commodification of traditions and rituals that can lead to erasing a deeper connection to the environment and an ability to read natural signs (Nazaruddin 2022). This, associated with social change, including rising economic imperatives, led to developing a scepticism of evacuation signs and preparedness outreach. Specifically, it weakened the collective memory of Anak Krakatau as a potential hazard. A participant, a descendant of an 1883 victim, mentioned that many people left Labuan after the 1883 tsunami. However, migration rates into this tsunami-prone area have been increasing. This contrasts with the more 'sedentary' Simeuluens who have preserved a memory of the 1907 tsunami through oral tradition and have largely avoided the catastrophic effects of the 2004 tsunami (Rahman, Sakurai and Munadi 2018; Sutton *et al.* 2021), which was tectonically induced and has influenced Indonesian collective memory and procedures.

Disaster cultures and the InaTEWS institutions, instrumentation and procedures were aligned before 2018 and are only marginally less so since 2018. This study showed that all participants reported perception changes. This was especially so for community members whose firsthand experience differed from what they had been taught about tsunami and their risk awareness and preparedness had increased. This was also reflected in people self-evacuating after earthquake in August 2019 and January 2022 in response to natural signs of tsunami. However, local government and emergency management actions did not follow. Material and training remains inadequate in addressing non-tectonically induced tsunami. While there are efforts to improve planning, BPBD's capacity and the installation of new instrumentation, such as sea-level monitoring devices, these actions have yet to result in improved coordination and preparedness efforts.

Cultural factors are important. Major disasters like the 1883 and 2004 tsunamis have been argued to significantly shape community perspectives, memories and preparedness (Gaillard, Clavé and Kelman 2008; Solnit 2009). However, the depth of these changes is worth questioning. The 2004 earthquake-triggered tsunami without doubt had a long-lasting and profound effect. It led to the establishment of the InaTEWS in 2008 and to the geophysical BMKG agency being assigned as the lead tsunami agency. In contrast, observations suggest that the 2018 tsunami led to short-term lessons learnt that were not consistently applied. In Labuan, all other agencies than BMKG still considered their role as 'mere users' of tsunami information. Agencies have developed a strong sense of ownership and expertise within their specific domains, hindering effective information sharing and collaboration during emergencies. The key challenge lies in fostering collaborative environments among agencies, reflected in shared procedures. For social groups institutionalised through laws and mandates, disaster cultures evolve and solidify over time. In the Indonesian context, achieving systematic reform that breaks down silos is contingent on a robust political will at the highest levels.

Ultimately, (mis)alignments between disaster cultures and the InaTEWS are of little effect if local risk profiles are not considered. The devastating effect of the 2018 tsunami in Palu and Sunda Strait and further possibility of non-seismic tsunami (Zorn *et al.* 2022) underscore the need for disaster cultures to not centre on seismically induced sources. Cascading hazards result from combined volcanic, hydrological, geophysical and social dynamics and this must be reflected in a comprehensive multi-risk approach and inter-agency alignment. Local knowledge and experiences must be incorporated into policymaking and preparedness strategies to include the risks and challenges communities face. Without official warnings, other natural signs such as roaring sounds, tremors and white sea foam can serve as warnings for communities to take immediate life-saving actions (Rafliana *et al.* 2022). Therefore, these signs should be incorporated into risk communication and awareness campaigns.

Conclusions

Examining (mis)alignments following the triangle approach can help to assess if tsunami warning systems are comprehensive and relevant to local communities. In some cases, alignment between the 3 elements of local risk profiles, the InaTEWS and multiple locally present disaster cultures can be improved. This can be done by involving community members in warning technology maintenance, tailoring awareness-raising materials to the local risk profile and linking awareness-raising with existing local traditions. The *Haul Kalembak* ceremony can serve to reconnect communities with natural tsunami warning signs. More reform of the InaTEWS is necessary and must overcome cultural and structural barriers that have formed over time. By addressing (mis)alignments, authorities can help communities to understand and respond to tsunami risks, which ultimately enhances preparedness and reduces the negative effects of future tsunamis.

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