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Epistemic Oscillation: Living With Ocean Risks

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Abstract

The year 2024 marks two decades since the Indian Ocean tsunami, known as the Boxing Day catastrophe, which far surpassed other devastating geological events of the 21st-century on humankind. Paradoxically, the epitome of tsunamis carries regenerative agency. It moves science and technologies across territories, proliferates knowledge production, and boosts innovations of warning systems as a critical part of ocean risk governance. In many cases, humans gradually distanced themselves from memories of past events due to the "high risk and low return period" of events. Through diverse risk perceptions, cultures, and beliefs, coupled with rapid human mobilities, the once proliferated knowledge could also be unlearned and forgotten. When knowledge on tsunamis is scarce or about to become extinct, no earthly process greater than tsunamis could bring back and sustain such knowledge. Like tsunami waves, this article argues that knowledge also refracts and oscillates. This article proposes epistemic oscillation as a conceptual lens as one of the ways to understand complex human and non-human entanglements, highlighting humans' dependent relations to geological dynamics, using the cases of the Palu 2018 tsunami as a testbed. By doing so, the article also argues that such lenses are useful in tracing the importance of understanding ambiguities in tsunami risk governance. By deploying an affective turn to ocean materialities and micropolitics as research methods, this article proposes alternative ways to unfold the multiplicities of social and geological realities and epistemic mobilities in the hyper-complex challenges of knowledge integration and ocean risk governance.

Keywords

epistemic oscillation; Indian Ocean; micropolitics; oceanic events; tsunami

1. Introduction

The proliferation of knowledge after catastrophic oceanic events is fascinating to delve into. This article, in particular, is less interested in how knowledge is accumulated, and rather more in what ways tsunamis can potentially uncover or even further enforce their regenerative agency in bringing more diverse knowledge and sense-making realms to the surface. This article proposes epistemic oscillation as a conceptual lens to understand complex human and non-human entanglements, highlighting humans' dependent relations to geological dynamics, using the case of the Palu 2018 tsunami as a brief testbed. By doing so, the article also argues that such a lens is useful to trace the importance of understanding ambiguities in tsunami risk governance. By deploying an affective turn to ocean materialities and micropolitics as research methods, this article proposes alternative ways to unfold the multiplicities of social and geological realities and epistemic mobilities in the hyper-complex challenges of knowledge integration, ocean risk governance, and with hyper-objects like tsunamis. This article intends to address the question of not merely how different interests, disciplines, and political dimensions are connected or integrated, but rather examines the interwoven relations of knowledge-making with earth processes, which offers an alternative way of understanding and governing the risks extended by our oceans.

The article, therefore, highlights the importance of the onto-epistemological analysis of human and non-human relations, where we can benefit from the lenses of new materialism and assemblage thinking. This means that the article does not intend to disregard the epistemic framing of analysis, but rather moves slightly away from the traditions of human-centric and social constructivism approaches while sharing a fair share with the ontologies of tsunamis. The concept of epistemic oscillation is a lens and, simultaneously, a result of moving away from such merely anthropocentric arguments. By engaging with the ontology of tsunami waves—specifically studies on the physical nature of tsunami waves and oscillation characteristics—and translating the waves into the epistemic contexts, I argue in this article that tensions, power asymmetries, and issues on sustainability carried by the proliferation of knowledge can be better understood. I posit that epistemic oscillation as a conceptual lens provides us with an alternative angle to better comprehend the social productions of tsunamis that frame why certain societies lack preparedness or why certain interventions or warning system technologies tend to fail in the longer term (UNDRR & UNESCO IOC, 2019). Knowledge proliferates, travels, saturates, and later continuously *oscillates* through more upcoming events and is perpetrated by the many local and trans-local situatedness. This does not necessarily go in line with the logic of coastal development and disaster risk interventions. I argue that such patterns resonate with how tsunami waves physically oscillate, a back-and-forth motion from one extreme to another (e.g., Satake & Shimazaki, 1988).

The remainder of the article is divided into three parts. First, it probes the tsunami's regenerative capacities amid the current mainstream approach of studies on ocean risk governance and knowledge-making. As a gift, tsunami resurface what might be treasures for humankind. An illustrated vignette of a nearly extinct species that was "saved" by the waves is provided, which encourages readers to engage more with the idea of this article. The second part elaborates on the concept of epistemic oscillation (Rafliana, 2024) while scratching the surface of the methodological possibilities through the lens of new materialism and assemblage thinking. While doing so, this second part provides case studies from a palaeotsunami study and tsunami survivor stories in Palu, Central Sulawesi, Indonesia. Here, readers are invited to observe the diverse entities across temporalities that are brought together as assemblages of knowledge that entangle with

earthly events Finally, in the discussion section, the article posits arguments that instead of preserving the problematic anthropocentric divides, one could look at the value of ambiguities and further consider the importance of tsunamis, rather than merely posing them as threats and danger. By looking at the importance of tsunamis and appreciating the entangled effects and ambiguities, one might uncover the power tensions behind knowledge-making and rebuild more symmetrical human and non-human relationships in the knowledge-making processes that are essential in rethinking ocean governance.

The development of the proposed concept of epistemic oscillation (elaborated in Section 3) is intricately linked to the micropolitics of research methods and analysis while appreciating the inspiration both from new materialism and assemblage thinking and, importantly, from a conversation with a Japanese scholar (explained in Section 2). The discussion highlighted the quest for current research related to the usefulness of tsunamis, picking up from the 2011 Great East tsunami in Japan. On the other hand, new materialism' propositions lean towards appreciating the non-linear, uneven, and continuously changing material world, where the agency of entities co-produces the social world, be it human or non-human (Fox & Alldred, 2016).

I realized that looking at the complex entanglements of humans and their knowledge, tsunamis and warning system technologies extend beyond the constraints of my positionality. My upbringing in the western territory of Indonesia as a female social scientist working mostly in the male-dominated environment of natural scientists, engineers, and disaster risk reduction, and living almost constantly in an area where earthquakes and tsunamis are part of the social-making, are among the traits that shape the micropolitics in this research. They also affect how I work on the research questions while trying to think differently in an attempt to suggest alternative ways of thinking through/with tsunamis and ocean governance.

New materialism as an approach would encourage looking at both micropolitics and tensions in the research subject, but also the micropolitics of the research itself (Fox & Alldred, 2016). As many were transformed by the tsunami event in 2004, I also experienced how tsunamis have contributed significantly to my personal and professional trajectories. I appreciate this as a privilege connecting me with other scientists, events, and conventions, leading me to many experimental thinking processes. This privilege became part of my micropolitics to conduct this research and helped enable me to see knowledge integrations differently, i.e., when knowledge integrates with earthly forces.

I would not say that new materialism as an analytical lens is the single and best answer to understanding the ever-growing complexities of the world and earth-beings. New materialism at least offers a way of understanding such complexities. My political role in this research, or the micropolitics of research, is to admit the limitations in understanding the complexities of human and non-human interactions and even more the limitations of humans to comprehend the earth's behaviours. It is also suggesting to stand against the sole domination of language and interpretations of the earth as a being, or at least to understand that human (limited) interpretations come with consequences. Such an approach potentially provides additional insights and illustrations that go beyond what already exists in many publications, particularly in terms of thinking about alternative methods of appreciating and living with tsunamis. As a person entangled with the topic of tsunamis during the past two decades, I can say that the more I follow tsunami events, the more the waves shape me, the way they behave, and offer uncertainties, which encouraged me to speak on the importance of the waves as many of our ancestors had already advocated, beyond the narrated threats and

hazards. In this argument, we shall proceed to discuss the generative capacities brought by non-human beings such as tsunamis.

2. The Generative Capacities of Tsunamis

Knowledge has always been appreciated as a determinant factor in governing the ocean (Hornidge et al., 2023) and reducing ocean-related disaster risks. Such determinacy affects and has been affected, among others, by the foreseen outcomes of the UN Decade of Ocean Science for Sustainable Development: a clean ocean, a healthy and resilient ocean, a productive ocean, a predicted ocean, a safe ocean, an accessible ocean, and lastly, an inspiring and engaging ocean (UNESCO, n.d.). As much as the vision and mission of the UN Decade of Ocean Science focus on ocean matters, the main actors and benefactors defined are humans and their well-being, and the ocean is narrated as the "Ocean We Want."

The Tsunami Ready program and the Safe Ocean Laboratory event are among the championing targets in achieving safe ocean outcomes. The topics related to the mitigation and preparedness of communities for ocean hazards, such as tsunamis, were facilitated by the Intergovernmental Oceanography Commission under the auspices of the UNESCO Tsunami Ready program. Under the UN Ocean Decade, the UNESCO Tsunami Unit has been spearheading the initiative to achieve the target of "100% of at-risk communities recognized Tsunami Ready by 2030s" by creating a UN Decade tsunami ready (UNESCO 2022), which has the goal of propelling efforts in community preparedness across the global ocean.

What I would like to highlight is not necessarily the question of how to achieve such an ambitious status of 100% of communities being prepared for any upcoming tsunamis by 2030. The promising intentions and good deeds of such programs have already been assessed elsewhere (Sakya et al., 2023). What interests me is how asymmetrical power relations are mediated, amplifying divides between humans and non-humans—including ocean matters—through the ways in which oceans are expected to behave and serve human interests. There were exponential changes in tsunami knowledge from merely a "harbour wave" experienced by fisherfolks and coastal dwellers to an imminent threat and hazard, exposing human vulnerability and capacities to oceanic risks. Such delineations are expressed, for example, in the Tsunami Glossary published by UNESCO IOC in 2019, which refers to tsunami warnings as "an alert, usually issued by a National Tsunami Warning Centre (NTWC) to indicate that a tsunami hazard is expected and imminent" (UNESCO IOC, 2019, p. 36). Such understanding propels social movements, governance, and the technicalization of humans against tsunami waves through advancements in science. Knowledge about the waves has created affordances to shape new institutional functions, delineating what is hazardous (Rahayu & Comfort, 2023) and what is not, who gets to delineate, issues of authority and sovereignty, and more.

I will now address what is meant by tsunami affordance. I learned an interesting and I gained valuable insights through a communication exchange in 2022 about my doctoral research topic with Japanese scientist Dr. Noriko Uchida. Dr. Uchida is an ecosystem resilience specialist from Tohoku University Japan, whose appreciation of human and non-human entanglements sheds light on the active role played by these troubled waves in changing lands and environments. Dr. Uchida pointed out that the Great Tsunami that hit Japan in 2011 had invigorated some endangered species, e.g., *Monochoria korsakowii*, locally known as mizuaoi, which is a weed-like plant from a hyacinth family. Weeds are used by Japanese coastal dwellers for household purposes, to make textiles, weave into ropes, and are also offered at shrine rituals. These species

once played an important role in the life of coastal dwellers along the Sanriku area and other Japanese coasts. The weed was once tied very closely to human existence. The massive energy that the tsunami brought during the 2011 event was enough to excavate the remaining endangered marsh plants that once threatened to become extinct due to human activities and a low genetic diversity level (Chen et al., 2023). As an ecologist, Dr. Uchida observes this phenomenon as the positive effect of tsunamis. The resurgence of this particular species showed that tsunamis are beyond hazards and threats to nature, as they can simultaneously reveal the threats humans pose to other species. Despite their volatility, not many studies have been conducted on the usefulness of tsunamis. Dr. Uchida explained that it is much easier for ecological scientists to think about how certain earth behaviours treat ecologies and surrounding environments. However, it is not easy to fathom that the waves could have positive effects on humans. Now that tsunamis are conceptualized basically as oceanic beasts, the phenomena have become gravely reduced into terminologies of threats and hazards. This is an interesting paradox, where such a reductionist view of the non-human entities would come at a price (van Loon, 2019).

The price one has to pay when relying solely on social constructions of the world might be the failure to grasp earth-human-technology relationships beyond how humans know what humans know. Keller (2019) agreed with Whitehead's arguments (Whitehead, 1978, as cited in Keller, 2019, p. 151): "[If] we desire a record of uninterpreted experience, we must ask a stone to record its autobiography. Every scientific memoir in its record of the 'facts' is shot, through and through, with interpretations." This is an almost cynical assumption that stones must be asked to record its being-ness cost as the price of ignoring the agency of rocks and hence soils, tsunami waves, earthquakes, and other relevant natural processes that shape the way humans live. In the next section, I will use an example of a method of interpreting earthly processes through a palaeotsunami by highlighting research on understanding past or prehistoric tsunami events from the materialities of littoral spaces, sands, sediments, and fossils. If Whitehead's statement is taken as the only truth, which seems to be what Keller is attempting, not only do we risk failing to make space for the ontology of tsunami deposits, but in this case, we also risk failing to express their agency in terms of keeping stories of past tsunami events through its layers of sands and preserving the histories of events. It also challenges the possibility of (inter)transdisciplinary science remedying the limitations of interpretations.

To trace studies related to tsunamis and its onto-epistemology, the current trend is not very promising. Social studies on tsunamis predominantly descend from natural science and engineering. These two science disciplines were responsible for announcing tsunamis as a scientific terminology and as a science during the International Union of Geodesy and Geophysics convention in 1960 in Helsinki. Years after the establishment of tsunamis as a science, many followed by empathising with the social dimensions of tsunamis, in which studies highlighted vulnerable communities. Studies on social vulnerabilities emerged in the 1990s. As research on tsunamis exponentially grew after the 2004 Indian Ocean event, studies on the social dimensions of tsunamis also proliferated, of which topics of research were advanced around economic livelihoods, risk perceptions, impacts of tsunamis on human health, reproduction, education, and policy implications. This comes in light of the ever-changing coastal regions, with the increase of human mobilities, and at the same time segregation of the many populations which, in turn, increases their vulnerabilities. These elements of humans and their environments are factored into the current mainstream of risk analysis and risk reduction perspectives. In this sense, social science has recently emerged even more prominently.

The University of Delaware is an example of social science leadership in the realm of disaster risks, claimed as the first research centre for social studies on disasters that was established in 1963 (Cox et al., 2019). The main aim of the centre is to provide knowledge for better risk management planning. However, the departure of collective social thoughts was in line with those of natural science, i.e., how to address hazards and alleviate vulnerabilities. Similar to the domain of sociology, much is put into the attention on policy processes and post-disaster interventions that include social issues of disaster victims and efforts to restore their social lives after a calamity runs its toll (Hettige, 2023) and less on, for example, the entanglements of the social dimensions of technologies, and warning systems. Sociology studies in tsunamis are far scarcer, and from the few that do exist, most also discuss studies with similar anthropocentric views. Nevertheless, this in itself is also evidence of the regenerative capacities of tsunamis beyond the metaphoric sense; the growth of multi-disciplines, social, natural, engineering, and more interdisciplinary approaches around the topic follow the recurrent of tsunami events.

Without challenging oneself on the genealogy of disaster studies, these approaches, I argue, bear consequences of technicalization—or, as Li (2007) terms it, rendering technical and compartmentalizing that are descendants of postcolonial practices of knowledge. Those in the darkness of knowing should be enlightened, and those vulnerable to tsunami risks should be prepared. An asymmetrical approach at the same time brings in questions of reciprocities, power asymmetries, inclusions, exclusions, and claim-making. The manner in which tsunamis are understood scientifically as hazardous speaks to reconstruction projects after an event, in which the patterns of responses had forcibly prevented coastal dwellers to re-establish their livelihoods by planning ahead and moving them to "safe zones" (Clark, 2010), creating what locals call "the second tsunami" or the "real tsunami" (Darmanto & Rafliana, 2023). Through the generative capacities of tsunamis, one could perhaps look at alternative ways of appreciating, understanding, and living with the waves.

Some studies from a different lens are likely among the most transdisciplinary endeavours by individual social scientists that emerged after the 2004 tsunami, following a series of consecutive tsunami events worldwide. These studies examine the more intimately entangled relationship between humans and non-humans. While working around the notions of human vulnerability, critical geographer Nigel Clark (2007) wrote a paper on the generosity of the volatile earth, responding to the Indian Ocean tsunami in 2004. Anthropologist Stefan Helmreich (2006) also reported his conversations on tsunami science with Indian anthropologist Amitav Gosh freshly after the 2004 tsunami and ethnographic observation of a scientific meeting in India in his paper on the collision of political and geological time of the tsunami. In his report, he underlined the uncertainties and agential forces of the tsunami waves that overwhelmed science and its capacity to understand the 2004 event. Later, in 2023, Helmreich published *A Book of Waves* and set under the spotlight the non-human agency of waves in many forms as means, perhaps with noble and ambitious intentions, to assess science and humanity. These approaches include the non-human perspective, in which one could expand the perspective towards the horizons and, at the same time, include oneself in the dialogue in much more reflective ways.

Following the Chilean tsunami in 2010, urban anthropologist Ignacio Farías took the science and technology studies stance in urban studies, underlying tsunami waves as crucial actors and as important entities of coastal urban assemblages (Farías, 2014). Farías reminded us that humans learned about tectonic and tsunami forces for generations and arranged their lives around and co-existed with these forces. However, similar to Helmreich, it seems that there is an enormous capacity of tsunamis to overwhelm knowledge,

which, in most cases, continuously fails humans in attempting to recognise and deal with the waves (Farías, 2014). This was precisely the reason to position tsunamis as the enemy. The ways tsunamis are posited may conclude how humans deal with tsunamis through convincing advancements in warning system technologies or with the International Tsunami Ready Programme. Perhaps what is needed instead are more attempts to challenge these posits, inspired by the many scholars previously mentioned. A path in which science and technology studies could offer an experimental route to revisit contemporary ways of thinking and knowing about tsunamis, exploring how humans create technologies that are also entangled with their social consequences, all while placing a respectful spotlight on the waves beyond their merely hazardous nature. Clark, in his book *Inhuman Nature: Sociable Life on a Dynamic Planet*, wrote of the great challenges of such paths:

> Whatever disciplinary division endure in the corridors of learning, research, and policy-making, nearly everybody these days agrees that it makes good sense to look at the dynamic of the social and physical worlds together. It is much harder to reach an agreement about how best to do this, where to start, what weighting to give the respective forces and processes, and how to bring very different elements into the same storyline. It's difficult enough for social scientists, humanities scholars or earth scientists to come to a consensus among themselves, let alone to reach across meta-disciplinary divides—and a whole world of jostling interests and values—to attain some shared planetary vision. (Clark, 2010, p. 3)

This article is an attempt to experiment with the concept of epistemic oscillation, following the thought processes of the above-mentioned scholars, who, one way or another, I would argue, also took agency in oscillating knowledge after different tsunami events, be it the Indian Ocean 2004, Chile 2010, or other events, which further inspired this article and many others who study the social lens of tsunami science.

3. Resonating Tsunami Waves: Epistemic Oscillation

A few months before the Indian Ocean tsunami in 2004, I was already starting my early career in coastal management and coral reef rehabilitation. Of course, tsunamis were part of the events discussed as being among the ocean's threats to coastal dwellers. Stories on past tsunami events were shared in conversations in places I visited and with communities I engaged with, such as the 1992 tsunami in Maumere Flores, the 1994 tsunami in Biak Papua, and several others. However, not much tsunami awareness and public education was available during the time, particularly in many tsunami-exposed littoral spaces in Indonesia. I was responsible for developing a children's school book series on coral reef management and coastal conservation. I remember that tsunami risks were not part of the main concerns that the book addressed.

The 26 December 2004 Indian Ocean tsunami shocked the world beyond the exposed areas, impacting dwellers, tourists, scientists, humanitarian assistance offices, business and private sectors, the UN, high-ranking officials, local governments, and military forces. The magnitude of the disaster was among the most transboundary-devastating events in contemporary human history. This single tsunami event caused approximately 230,000 lives to be lost with a wide range of damage in 15 countries (Suppasri et al., 2012). The event had promulgated an exponentially high number of publications, reports, and scientific papers related to tsunamis. Synolakis and Bernard (2006) highlighted that tsunami studies before 2004 emphasized the hydrodynamic characteristics of the waves, with less sophisticated tsunami source modelling and a grave lack of understanding of the hazards that might pose a threat towards the Indian Ocean rim. Some of the

pre-existing scientific knowledge was regenerated by the 2004 Indian Ocean tsunami and was then re-invigorated or even unlearned due to the findings and studies of the aftermath.

Through the Publish or Perish engine search, out of approximately 1,000 papers, books, and reports (excluding media coverage) published in the last 75 years, i.e., from 1946 to June 2024, only about 10% were published before 2004. The topics grew significantly after the 2004 Indian Ocean tsunami to include a broad range from hazard and risk assessments and forecasting, tsunami modelling, warning systems, mitigation, relief, and relocation to studies on tsunami risk perception, ethnosciences of tsunamis, and local knowledge of hotel management and tourism industries related to tsunami risks, and to environmental changes and issues on sustainability and risk governance. Tsunami sciences were more strongly repurposed from understanding the wave characteristics to understanding human responses to natural and technological warnings toward saving lives (Eddie N. Bernard, personal communication, 2021). This was even more so after the Great East Japan earthquake and tsunami in 2011, a year in which there were 200 publications. Despite a relatively smaller number of events that followed, more than 800 papers were published from 2012 to 2024 on the 2011 tsunami event alone. Similar interesting patterns have emerged in other historical events, affecting local and trans-local enlightenment trajectories in understanding the world, such as learning from the Lisbon 1755 event and Japan Sanriku 1896 and 1933 events (e.g., Baptista et al., 1998; Shuto & Fujima, 2009; Trethewey, 2020).

Oscillation, borrowing the terminology from physical science and in its most literal sense, means the back-and-forth, swinging pendulum-like motions that apply to different forms of materials, including water, ocean waves, and tsunamis. Tsunami oscillation is commonly recognized as a terminology in tsunami science, referring, for example, to the resonance of tsunami wave amplitudes in harbours and bays. The waves have to be “excited” to oscillate, be it by vertical displacement of the water column due to earth fault ruptures or other material disturbances such as underwater landslides, volcanic eruptions, and many more (Tetsuo, 1984; Jia, 2017; Lepelletier, 1981). The wave heights increase rapidly to evolve and decrease over time and distance.

Thinking about ocean waves, oscillations, and how they affect social changes is part of the affect and ontology turn in social science. Helmreich discussed social oscillations in *A Book of Waves*. He expedited that ocean waves, winds, rainfalls, and currents shape the structure of coastlines (Helmreich, 2023). So, discussing epistemic oscillations and aligning the ideas of Helmreich is not something new. The newness of this concept of epistemic oscillation that I would like to emphasize here is the prerequisite roles of tsunamis in the social production of knowledge, particularly scientific knowledge. Tsunamis are not only possible or likely to shape and advance scientific knowledge and create social change: they must happen, and thus, tsunamis are vital. This also emphasizes the importance of both ethnoscience and modern sciences in respecting earth systems where earthquakes and tsunamis are important heartbeats, a perspective which will have different meanings and interpretations for science into policies and actions.

When observing the way tsunami knowledge and science proliferate and advance, there are dire similarities within which the social productions of knowledge mimic tsunami oscillations, where engagements of science, development of laboratories, and exchanges of scientific findings escalate and are excited by tsunami events. Humans can only do so much in sustaining knowledge and science before such knowledge becomes saturated and loses its pace until another tsunami event occurs: the greater the magnitude, the greater the impacts. It makes sense to follow the rhythms of oscillating ocean waves and acknowledge the agency of tsunami

waves in the production processes of knowledge and science as they are further developed and sustained. Particularly in the case of the social production of tsunami science, the happenings of tsunamis and their entanglements of different human and non-human entities are indispensable and are almost a prerequisite.

To implement the concept of epistemic oscillation, let us now move to the case of Palu, an urban coast in Central Sulawesi, Indonesia, that has been shaped by centuries of tsunami events for its placemaking. The territory is set upon complex junctions of multiple earth plates and fault systems (Socquet et al., 2006, as cited in Putra et al., 2023). The areas were severely impacted by earthquakes, colossal liquefaction, underwater landslides, and massive tsunami waves on 28 September 2018 that took at least 1,100 lives (Triyanti et al., 2023). However, historical records, which are available only since the early 1900s, show that Palu is also among the territories where the reoccurrence of tsunamis is exceptionally frequent (1927, 1938, 1968, and 1996; Putra et al., 2023).

A first-ever study on the geological evidence of past tsunamis, known as palaeotsunami studies, in this area was conducted a few years later and led by Putra et al. (2023). The study documented layers of coastal soils excavated approximately 200 m from the tip of the Palu Bay coast, digging around 100 cm deep. This captured layers of distinct soil in different depths which indicated at least three tsunami events that occurred in the past several centuries using methods of carbon dating to identify the age of the layers. The layers serve like a photo album of past historical events: the first layer was found at a depth of around 80 cm (suggesting a tsunami around 1869), the second was around 60 m (1755), and the third was around 30 cm (1657). These three layers of soil have a lighter brown colour compared to the adjacent soil layers above and below. In addition, the layers showed a larger number of damaged foraminifera specimens, indicating the energy that the past tsunamis had brought while surging inland and thus bringing these species along as the tsunami exposed sands and soils that were gradually buried by new layers of soils (Figure 1).

The earth's memories, later interpreted through palaeotsunami studies, and human memories of tsunamis were brought together by the Palu 2018 event. Tsunamis became a "gift" when human memories were not capable of preserving events centuries back, as the palaeotsunami soils would. Indigenous communities preserve memories of past tsunamis and liquefaction and reside in the suburban and rural villages of Donggala, adjacent to Palu Bay. This is, of course, not without a rational logic, since humans retreated due to the devastating impacts of tsunamis on the livelihoods of coastal dwellers. Such a retreat also comes with new vulnerability, as past events went unlearned due to high human mobility.

On the other hand, although the recurrence of past events seems to be quite frequent, trans-generational knowledge was also not necessarily passed through. The memories of more recent tsunamis, e.g., 1927, 1938, and 1968 (Putra et al., 2023; UN for Disaster Risk Reduction, 2019), that affected the areas were kept among a few survivors who were rural dwellers. The more temporally distant the event, the more it is forgotten. As such, epistemic oscillation also applied to the temporality of the case, where the knowledge and response capacity in 2018, at least to several Indigenous dwellers, in many ways resonated from memories of the past, even from the 1938 event.

An elder in one of the villages was a survivor of the 1938, 1968, and 2018 tsunami (UNDRR & UNESCO IOC, 2019). In an interview, he passed a story from his parents on where to go if there were mishaps occurring. The word tsunami was not a known terminology at the time and locals called the event *Bombatalu*, which

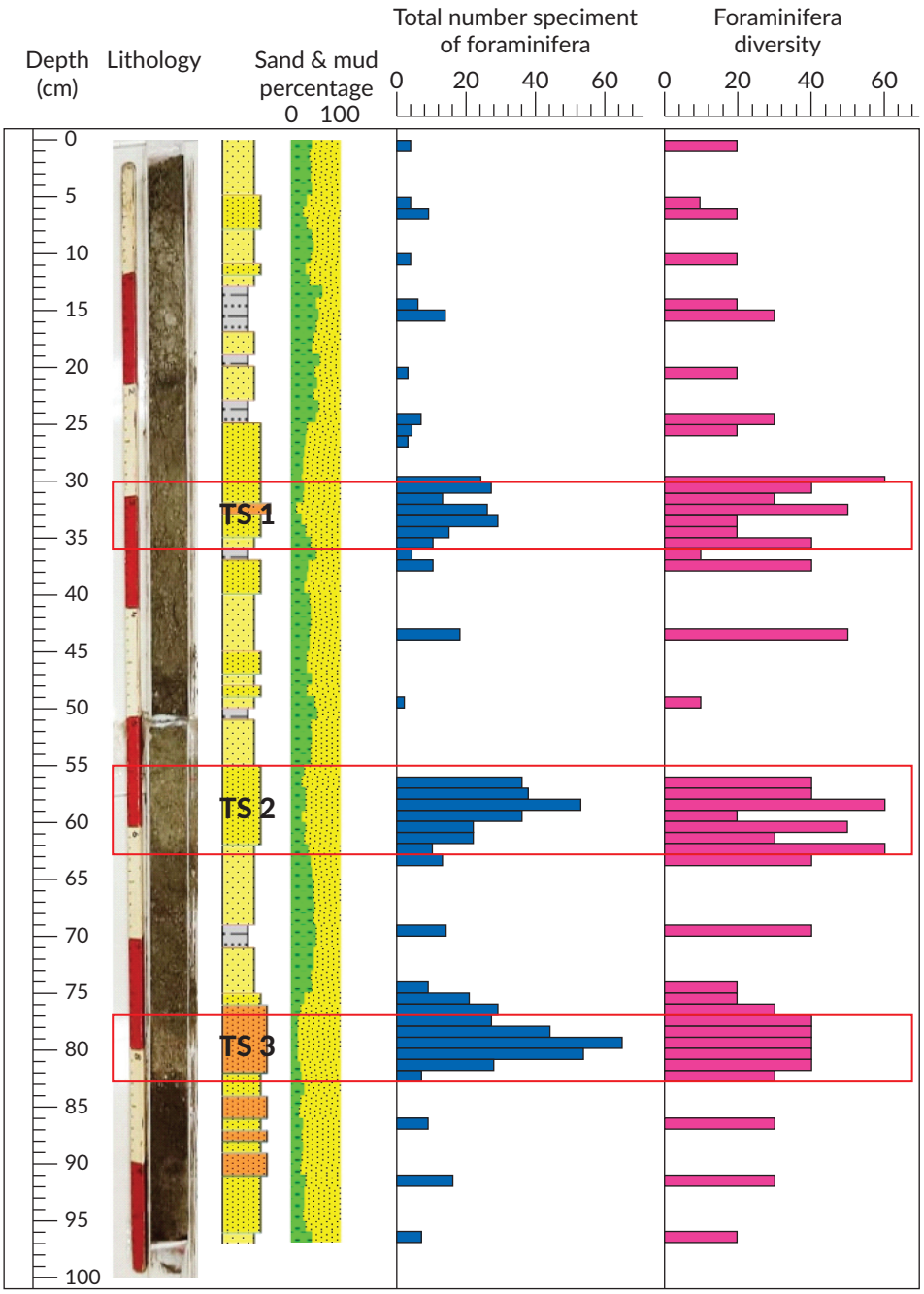

Figure 1. The layers of tsunami sand deposits in Palu Bay, Indonesia. Note: TS1, TS2, and TS3 are palaeotsunami layers (tsunamis that occurred in prehistoric times). Source: Putra et al. (2023, p. 490).

means the three waves. Knowledge about the waves materialized into ethnoscience, where the elder shared that his ancestors knew where to go and which hills to avoid from landslides and collateral catastrophes. However, this knowledge was not necessarily transferred to younger generations, due to certain customs and taboos forbidding such stories to be told or passed along. Even the wife of this elder did not know about the 1938 event before 2018 happened when her husband finally shared his knowledge about his tsunami history. The tsunami event brought his preserved memories back to life.

Modern science grew rapidly after the 2004 Indian Ocean tsunami, which affected the far west coasts of Indonesia. Education interventions reached Palu and were introduced by local non-government agencies, the local government, and scientists. However, the education messages miscalculated the possibility of the 2018 scenario and were translated much differently. It is fair to conclude that modern knowledge and technological fixes found their limits in preventing fatalities. Communities complied with the tsunami risk assessment and tsunami drill training scenario about six years before the 2018 event. The scenario assumed a 15-minute lead time to reach a safe place. The 15-minute lead time was merely among the many possible tsunami scenarios applicable to the region's context, and unfortunately was not the case when the 2018 event occurred. The possibility of moderate earthquake-inducing underwater landslides was not factored into the rather deterministic scenario upon which risk reduction strategies, established several years earlier, were built. The tsunami turned quite differently and caught many by surprise with less than five minutes of arrival after the massive earthquake, leaving an impossibly short amount of time to run to safe grounds as instructed (UN for Disaster Risk Reduction, 2019).

These experiences and knowledge travel back and forth, oscillating across different territories, temporalities, conventions, and epistemic groups, from scientific papers to preparedness and countermeasures as well as mitigation efforts. In certain periods of "peace," collective knowledge potentially diminishes. Epistemic oscillations collide with the inhuman nature of earth forces which humans tend to try to control but are actually dragged into, in back-and-forth motions of learning and forgetting, of constructing and reducing meanings of the waves, of dispersions, dissemination and saturations of social processes, of the excitement of "new" findings, confusions, and negotiations, of the emergence of "new power," resistances, domination, and dependencies. All of these are afforded and, at the same time, constrained by non-human forces: earthquakes, tsunamis, and earthly processes. They are also afforded by the materiality of other non-human forms: observation instruments, warning systems, detection devices, and other technological artefacts.

4. Conclusion

Moving in and out from a human-centric analysis of knowledge-making through discourses to attempting to centre-stage the earthly being is admittedly intricate. It follows with an abyss of temporal and spatial differences applied to geologies and humans in an effort to examine alternatives of dualities in the analysis through new materialism and assemblage ways of thinking. As the Great East Japan 2011 tsunami relived the important yet endangered species of mizuaoi in Japan, the Palu tsunami relived and revealed memories from both humans and the earth, demonstrating interdependency relations, or rather, human dependence toward earthly processes to allow growth and oscillations of knowledge. As such, tsunamis shall no longer merely be framed as a "hazard" or "threat," as tsunamis are beyond these misnomers. A possibility that Fox and Alldred (2016) elucidate is removing, or rather disassembling, the dualisms between the physical world of things and bodies and the realm of thoughts, social structures, and cultural products, as well as reassembling the diverse and overwhelming entities that accommodate realities independent from human thoughts or knowledge, while at the same time weaving in diverse, evolving, and socially constructed knowledge into a storyline. In doing so, analyzing the social intricacies behind scientific texts and technologies is to a greater extent possible, i.e., scrutinizing the transcendental behind (tsunami warning system) machines. Also, such a perspective will discuss the possibilities of understanding ambivalences and paradoxes, including gifts brought by natural forces. To take this further, we should explore the inseparable ambivalences as part of future research and policy agendas once we aim to better understand complex and cascading ocean risks.

The turn to new materialism is not objecting that humans operate through interpretations. It instead highlights the problems of the power of language and interpretations that are being scrutinized. For the palaeotsunami study, it is the power and (scientific) language used to interpret the meaning of these layers. The interpretation may be used to delineate hazardous areas due to the evidence of past tsunami events that are used as the foundation to regulate future ones. Once the hazard areas are delineated and legitimized, they become important information for tsunami risk reduction measures, but at the same time, they are prone to social tensions and contestations, where ports, dwellers, the tourism industry, businesses, and coastal inhabitants are convinced that they are now living with tsunami risks. I further argue the importance of understanding and empathizing with these paradoxes and ambiguities to develop, for example, more sensitive risk communication and many other uses.

Through a new materialism lens, the sociology of knowledge also lends a better and more reasonable understanding of tsunamis' important and generative roles and ontological features. Tsunamis are more than merely a construed "hazard," and I argue here that the narratives around tsunamis as such have grown to become more reductionist since human understanding about the waves through the sciences has proliferated, along with advancements in communication and transportation technologies, science infrastructures, and funding that allow a more thorough and deeper understanding of tsunami events.

Epistemic oscillations are where and when knowledge integrates with earth processes. Such proliferations are tied to the dynamics and happenings of earthquakes, tsunamis, volcanoes, and other so-called natural hazards. The ambiguities lie in what knowledge has been unlearned. Risk perceptions diminish when the earthly processes are felt or seen as distant, both spatially and temporally. This is the case for tsunamis, which have long return periods and carry many epistemic and ontological uncertainties. This means that uncertainties due to the limits of human knowledge and capacity to understand the earth's dynamics along with its geological and social complexities are important dimensions of governing risks (Triyanti et al., 2023). Ambiguities also lie in the interpretations of realities, which are often framed and accepted as truth. This comes with grave consequences, as illustrated in the Palu tsunami case.

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Conflict of Interests

The author declares no conflict of interests.

Data Availability

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