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Living in-between: Implications of local risk perceptions for the management of future eruptions at the Calbuco and Osorno volcanoes (Ensenada, Chile)

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ABSTRACT. Since the perceptions of communities at risk play a central role in managing future emergencies, contingency plans must consider the appropriate involvement of the perspectives of exposed populations. This article addresses the case of Ensenada (Puerto Varas, Chile), a settlement located in the area of direct influence of the Calbuco and Osorno volcanoes. They respectively rank 2nd and 8th in the list of highest-threat Chilean volcanoes. Here we depict the multiple risk perceptions of the inhabitants of Ensenada and the integration of human perceptions into volcanic emergency management through qualitative research, based on semi-structured interviews and documentary analysis. Our results illustrate that Ensenada represents a settlement critically exposed to multiple hazards from both volcanoes, intertwined with a series of social conditions that influence individuals' self-perception as vulnerable to future eruptions and, simultaneously, as capable of acquiring conditions to strengthen disaster preparedness. Moreover, the locals are eager to participate in future emergency management planning and adopt preventive attitudes at community, household, and individual levels. Based on these results, we highlight the advantages of a better understanding of the causes of perceived risk and its integration into emergency management strategies for future eruptions, in order to visualise how people make sense of daily life and disaster preparedness in the midst of active volcanoes.

Keywords: Volcanic risk perception, Local disaster risk management, Local community, Ensenada, Southern Andes.

RESUMEN. Vivir entre medio: implicancias de las percepciones locales del riesgo para la gestión de futuras erupciones en los volcanes Calbuco y Osorno (Ensenada, Chile). Dado que las percepciones de las comunidades en riesgo juegan un papel central en la gestión de futuras emergencias, los planes de contingencia deben considerar la adecuada participación de las perspectivas de las poblaciones expuestas. Este artículo aborda el caso de Ensenada (Puerto Varas, Chile), un asentamiento situado en la zona de influencia directa de los volcanes Calbuco y Osorno. Estos ocupan respectivamente el 2º y 8º lugar en la lista de volcanes chilenos de mayor amenaza. Se describen en este estudio las múltiples percepciones del riesgo de los habitantes de Ensenada y se explora la integración de las percepciones humanas en la gestión de emergencias volcánicas mediante una investigación cualitativa basada en entrevistas semiestructuradas y análisis documental. Los resultados aquí expuestos ilustran que Ensenada representa un asentamiento críticamente expuesto a múltiples amenazas de ambos volcanes, entrelazadas con una serie de condiciones sociales que influyen en la autopercepción de los participantes como vulnerables a futuras erupciones y, simultáneamente, como capaces de adquirir condiciones para fortalecer la preparación ante desastres. Además, los habitantes de Ensenada se manifiestan deseosos de participar en la planificación de la gestión de futuras emergencias y adoptar acciones preventivas tanto comunitarias como familiares e individualmente. Sobre la base de estos resultados, se destacan las ventajas de una mejor comprensión de las causas del riesgo percibido y su integración en las estrategias de gestión de emergencias para futuras erupciones, con el fin de visualizar cómo la gente da sentido a la vida cotidiana y a la preparación ante desastres en medio de dos volcanes activos.

Palabras clave: Percepción del riesgo volcánico, Gestión local del riesgo de desastres, Comunidad local, Ensenada, Andes del sur.

1. Introduction

Chile is a socio-natural laboratory to study dynamic and often highly fragile spaces, such as mountain areas and volcanic landscapes, alongside the diversity of human response to volcanic activity (Carn *et al.,* 2009; Camus *et al.,* 2016; Sandoval and Voss, 2016). Its geographical features include the physical configuration of active volcanism due to its location in front of a subduction zone and the so-called Pacific Ring of Fire (Stern, 2004). Therefore, living in a country exposed to volcanic eruptions requires society to be prepared to anticipate and mitigate their effects at all levels. In this sense, the management of natural hazards requires taking into account the social and cultural contexts of the places where they materialise, which reveals the socio-natural character of disasters (Cannon, 1994), insofar as nature is not something static and passive but a moving agent that affects and influences social action, and vice versa (Romero and Romero, 2015; Clark and Yusoff, 2017). Society's response to volcanism is thus deeply related to disaster risk management, understood as a multidimensional phenomenon in which humans can make decisions and actions to prevent significant damage from natural hazards, which are often inspired by the way they culturally perceive disaster risk.

Exploring disaster risk management requires considering the vulnerability conditions as another factor that interacts with natural hazards producing disaster risk. Vulnerability as a variable in disaster risk analysis emerges after a critical reflection on physical, social, economic, and environmental conditions (Wisner *et al.,* 2004; Lavell, 2009), both individual and collective, that make populations vulnerable to the impacts of extreme events. According to Cannon (1994), hazards are natural, but for a hazard to become a disaster, it must affect vulnerable groups. Vulnerability encompasses material aspects related to a limited, or lack thereof, of social, economic, and/or political capacity to cope with physical impacts and recover from a catastrophic event (Quarantelli, 1998; Wisner *et al.,* 2004). Factors such as corruption and poverty might also contribute in increasing people's vulnerability, facilitating disasters (Favereau *et al.,* 2018). On the other hand, vulnerability also implies immaterial aspects expressed, for instance, in people's self-perception as vulnerable or exposed to risks in their inhabited environment. Perceptions are shaped by attitudes, behaviours, and socio-economic, political and cultural influences to which individuals, families and populations are subjected (Hoffman, 2015; Bayón-Martínez, 2016).

Volcanic geographies such as Colombia, Mexico, Ecuador, Italy, and the Philippines are examples of cases that have considered the active participation of citizens in disaster risk management policies, enabling the empowerment of communities in their role in the face of emergencies (*e.g.,* Barberi *et al.,* 2008; Carlino *et al.,* 2008; Gaillard *et al.,* 2008; Ricci *et al.,* 2013; Calvache *et al.,* 2021).

To this end, it is central to explore mechanisms to involve community perspectives in the decision-making process of reducing risk in their territories, since a territorialised and cohesive community can better prevent or overcome a disaster (Gallegos *et al.,* 2021). One of the main ways researchers in volcanic contexts have used is disaster risk communication through participatory strategies and mechanisms, which bridges the natural gaps between local communities, risk management practitioners, and scientists (*e.g.,* Douglas *et al.,* 1998; Alexander, 2000; Davies *et al.,* 2015; Doyle *et al.,* 2015; Fearnley and Beaven, 2018). Improving the management of volcanic emergencies is more feasible by incorporating and understanding the role of local participation and local perceptions, and by paying attention to the cultural background of communities (Oliver-Smith, 2016), as their narratives include aspects of their vision as local people interacting with volcanic risk in everyday life.

In Chile, the heterogeneous distribution of populations and particularly their differing social characteristics make specific towns or localities more vulnerable to a volcanic eruption (Calderón *et al.,* 2012). Such is the case of Ensenada (Los Lagos region, southern Chile), a small town located between two of the volcanoes with the highest specific risk according to the Chilean Geological and Mining Service's ranking (Sernageomin, 2023[1]): the Calbuco volcano (2nd place) and the Osorno volcano (8th place). The last eruption of Calbuco was in 2015, and that of Osorno in 1835 (Bertin *et al.,* 2015; Romero *et al.,* 2016; Morgado *et al.,* 2022). Ensenada's volcanic landscape, shaped by a number of geological and ancient glacial processes, supports various economic activities associated with subsistence activities and tourism, due to the availability of key resources such as soil, forests and water. However, due to

1 Sernageomin. 2023. Ranking de riesgo específico de volcanes activos de Chile. Red Nacional de Vigilancia Volcánica, Servicio Nacional de Geología y Minería, Gobierno de Chile: 1 p.

their location, these livelihoods are exposed to the impacts of volcanic eruptions, which, in many cases, are historically essential elements in constructing resources beneficial to societies (Rubiano, 2009). In this sense, volcanoes are also often part of the livelihoods of communities, especially in tourist and/or rural territories in southern Chile (Marín *et al.,* 2020; Vergara-Pinto and Romero, 2023). The appropriate response to future volcanic events is therefore fundamental to mitigate their impacts on the population of Ensenada.

In order to contribute to volcanic risk studies in southern Chile, this article examines Ensenada as a case study to exemplify the intersection of geological and social processes. In doing so, the paper presents a systematic characterisation of the risk perceptions and the type of information held by the inhabitants of Ensenada about volcanic behaviour and the effects of past volcanic eruptions. This study therefore aims to: 1) describe the current risk management of volcanic emergencies that have affected the town of Ensenada, 2) analyse the inhabitants' perception of volcanic risk and the factors that influence it, and 3) propose strategic, high-level recommendations for incorporating risk perception into volcanic emergency management.

2. Conceptual approach to volcanic risk

The International Strategy for Disaster Reduction (ISDR) of the United Nations defines risk as the result of the interaction of two main factors, namely hazard and vulnerability. Disaster risk results from the combination of both, and is defined as the "probability of expected harmful consequences or losses resulting from interactions between natural or anthropogenic hazards and vulnerable conditions". Hazard refers to a physical event that is likely to produce potentially disastrous consequences (Henríquez *et al.,* 2011[2]; Olson *et al.,* 2020; UNDRR, 2020). On the other hand, vulnerability refers to conditions shaped by physical, social, economic, and environmental processes, which increase the susceptibility of a community to the impact of hazards (UN/ISDR, 2004). Therefore, risk implies an assessment that leads to a decision. Far from being straightforward, this assessment depends on the perspective from which risk is being studied.

The physical sciences often establish the origin of risks in hazards, classifying them as either natural or technological, a classification that can be practical for limiting the physical events that can occur in a specific place and time. However, disaster risk emerges from the interaction of hazards with structural conditions embedded in social processes (Natenzon, 2019[3]; Andharia, 2020). These processes relate to the intersectional sources of social vulnerability, which varies according to the characteristics of each population or individual and their development (Reinhardt, 2019). In this context, intersectionality results in the fact that some social groups are more likely than others to suffer damage and loss in front of natural hazards. Critical features of these variations in impacts include class, ethnicity, gender, disability, and age or status, with the most vulnerable groups also having the most difficulties in rebuilding their livelihoods after a disaster (Blaikie, 1996; Cutter, 1996; Andharia, 2020; Romero *et al.,* 2022). Recently, the interaction of hazards and vulnerabilities as factors have been acknowledged in volcanic risk research (*e.g.,* Jóhanesdóttir and Gísladóttir, 2010; Jenkins *et al.,* 2014; Wilson *et al.,* 2014; Faas, 2016), shaping the way in which volcanoes are categorised. In this sense, the concept of *specific risk* arises, defined as the combination of the degree of threat and the level of exposure or vulnerability of the territory, which is related to "what is potentially affected before the application of mitigation measures" (Lara and Calderón, 2015).

All these social aspects combined with the source of natural hazards are embodied by individuals and communities. People assess risk in a different way compared to technical evaluations, which is then expressed in their risk perceptions. These perceptions are "based on cultural norms and values (...) and occur within the relationships that human communities have with their physical and social environments" (Oliver-Smith, 1993). The perception of risk influences the territoriality of human beings, configuring common spaces and multiple relationships through the mediation of its symbols, senses and meanings, regulating their social practices (Bayón-Martínez, 2016). Appropriate contextual and people-centred volcanic risk research need to therefore consider local people living in disaster-prone environments, as their experiences and perceptions of risk can shed light on their remaining vulnerabilities before facing a potential disaster (Romero *et al.,* 2022). Likewise, exploring the degree of familiarity with risk management policies at the

[2] Henríquez, O.; Jordan, R.; Saldaña-Zorrilla, S. 2011. Guía análisis de riesgos naturales para el ordenamiento territorial. Subsecretaría de Desarrollo Regional y Administrativo, Gobierno de Chile: 147 p.

[3] Natenzon, C. 2019. La problemática del riesgo y las catástrofes. Planteo de la cuestión. Curso FLACSO Tratamiento de catástrofes, riesgo y vulnerabilidad social, versión on-line: 14 p. https://www.flacso.org.ar/formacion-academica/tratamiento-de-catastrofes-riesgo-y-vulnerabilidad-social/

local level can help elucidate connections or gaps between decision-makers and at-risk populations, as well as local knowledge of disaster risk policies, such as the Sendai Framework for Disaster Risk Reduction 2015-2030, local emergency plans, and official warning and response systems, administered by Sernageomin and the Chilean Survey for Disaster Prevention and Response (Senapred).

Local risk management involves local leaders, often supported by external advice and technical actors (Lavell, 2003; Davies *et al.,* 2015). This vision allows risk to be expressed in a concrete, measurable or perceived way at the micro and local scale, mirroring the scales of potential loss and damage (Lavell, 2003). This is relevant as it is at the local scale where the differences in the impacts that the same natural phenomenon produces in different localities are best expressed, explained in terms of different sources of vulnerability, hazard, and capacities (Narváez *et al.,* 2009). Due to its characteristics, local risk management is presented here as suitable for analysing local perspectives on volcanic risk and how they can be integrated at the management level.

3. Background

3.1. Study area

Ensenada is located midway between the Osorno and the Calbuco volcanoes, on the southeastern shore of the lake Llanquihue, in southern Chile. Ensenada is part of the commune of Puerto Varas, which has 44,578 inhabitants (22,700 women and 21,878 men), most of them (68.2%) in the age range of 15 to 64 years (INE, 2017). The town of Ensenada has ~1,500 inhabitants. Ensenada is ecologically and economically inserted within the circuit of national parks, being nationally recognised for its tourist attractions, which explains the high number of floating population and second homes for temporary occupation in the zone. According to the Chilean Statistics Institute (INE), the most significant number of transient populations (*e.g.,* tourists) was recorded in the lake Llanquihue and lake Todos los Santos destinations, with a total of 858,044 people in 2019. Ensenada established and developed over a volcaniclastic fan composed by products from both Osorno and Calbuco volcanoes. These volcanoes and their eruptive activity are briefly described below.

3.2. Osorno volcano

The Osorno volcano (41°06' S, 72°20' W, 2,652 m a.s.l.) is a composite stratovolcano whose origins date back to the Middle Pleistocene (Moreno *et al.,* 2010). Volcanic hazards at Osorno (Fig. 1) are lava flows, debris flows (*e.g.,* lahars), and tephra fall (Moreno, 1999a). Recorded volcanic activity is most certainly identified from 1575 onwards, with confirmed eruptions in 1790, 1834, 1835 and 1837 (Petit-Breuilh, 1999), implying an average eruption frequency of ~60 years for VEI≥4 and ~20 years for smaller-scale eruptions (Romero *et al.,* 2023). The 1835 eruption is considered the most significant of Osorno in historical times in terms of intensity, impact, and erupted volume. This eruption formed thirteen eruptive vents organised in two fissures and evacuated 0.33 km^3 of lava and 0.17 km^3 of tephra (Lara *et al.,* 2013; Pérez *et al.,* 2019; Morgado *et al.,* 2022). Before the 1835 eruption, there was, on overage, one eruption every 43 years, however since the last eruption in 1835 no new activity has occurred. The historical eruptions were preceded by underground noises, perceptible seismic activity, and small, short-lived ash explosions (Moreno, 1999a). Monitoring of the Osorno volcano began in 1999 by the Southern Andes Volcanological Observatory (Ovdas), following the creation of the Chilean Volcanic Monitoring Network, which was complemented by the installation of one surveillance camera, 7 seismological stations, one accelerometer, and one inclinometer (https://rnvv.sernageomin.cl/volcan-osorno/).

3.3. Calbuco volcano

The Calbuco volcano (41°20' S, 72°39' W, 2,003 m a.s.l.) is a massive, truncated cone-shaped stratovolcano developed through successive stages of central activity since ~100 ka BP, emitting lava flows and pyroclastic products of monotonous andesitic composition (Sellés and Moreno, 2011; Mixon *et al.,* 2021). It is the 2nd highest-ranked Chilean volcano according to Sernageomin (2023). Ovdas monitors Calbuco by means of one surveillance camera, 7 seismometers, one accelerometer and one inclinometer (https://rnvv.sernageomin.cl/volcan-calbuco/). The main hazards associated with Calbuco volcano (Fig. 2) are tephra fallout, ballistic ejection, pyroclastic

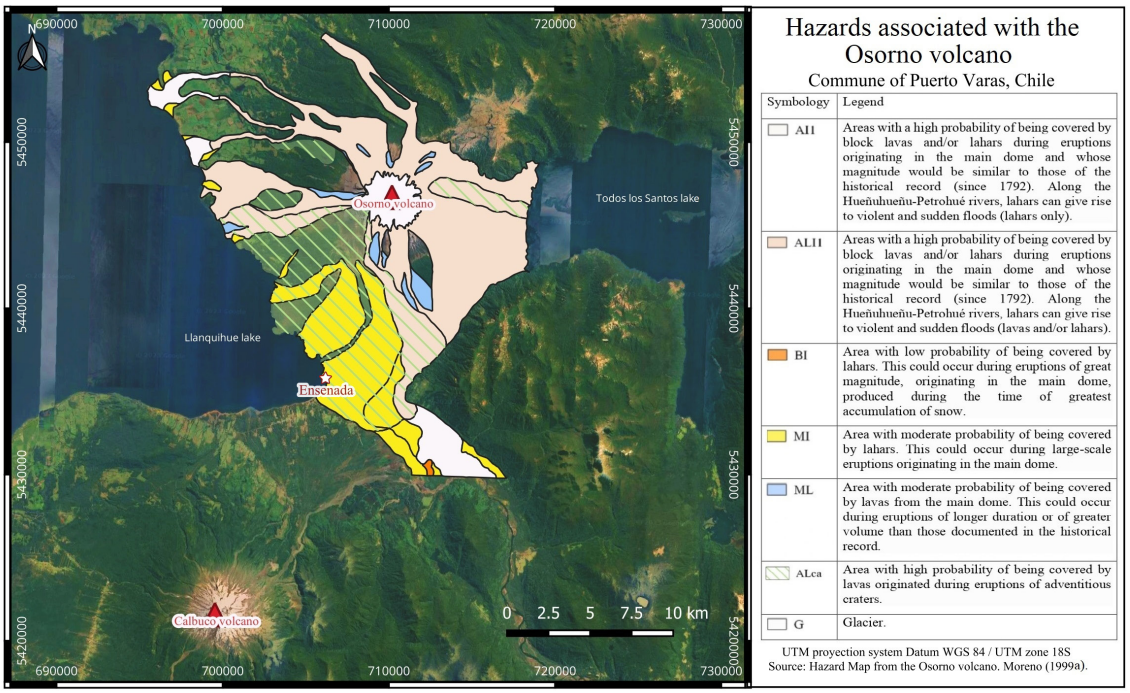

FIG. 1. Osorno volcano hazard map. Based on Moreno (1999a).

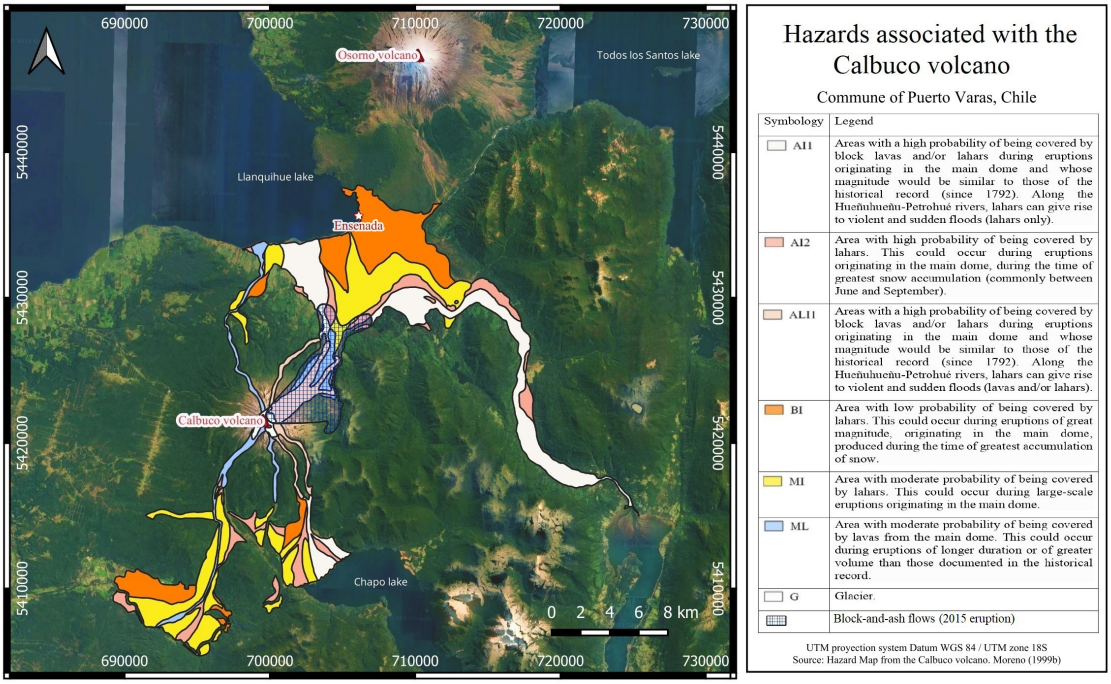

FIG. 2. Calbuco volcano hazard map. Based on Moreno (1999b).

density currents (PDCs) extending to the base of the volcano, lahars, and lava flows (Moreno, 1999b; Moreno *et al.,* 2006).

Volcanic activity at Calbuco has been frequent in the last two centuries (Petit-Breuilh, 1999), the largest occurring in 1893, 1961, and most recently on 22-23 April 2015. The 2015 eruption was initially characterised by a sub-Plinian pulse lasting approximately 1.5 hours, which generated an eruptive column of ~15 km a.s.l. The second pulse started some hours after, also sub-Plinian, which lasted ~6 hours and generated an eruptive column of ~16-18 km a.s.l. Combined, both eruptive pulses erupted ~0.28 km^3 of tephra (Castruccio *et al.,* 2016; Romero *et al.,* 2016). More than 570 timber buildings were affected by tephra fallout (thickness exceeding 15-30 cm), mostly in Ensenada and Petrohué to the north, whereas total damage occurred in buildings affected by lahars mostly at Correntoso and lake Chapo to the south (Hayes *et al.,* 2019). One week later, by 1st May, there were 6,685 evacuees at the regional level (Onemi, 2015[4]; Ruiz, 2016). Border crossings in the Los Ríos and Los Lagos regions had to be temporarily closed due to a lack of visibility (Ruiz, 2016). The houses and critical infrastructure located in the high hazard zones according to the 1999 maps were the most affected (Figs. 3 and 4). The hazard map of the Calbuco volcano generated ~15 years earlier demonstrated their validity and relevance (Romero *et al.,* 2016).

3.4. Ensenada's tourism exposure scenario

The Calbuco 2015 eruption caused economic losses, damage to infrastructure, and a heterogeneous impact on livelihoods (Fig. 4; Table 1). Examples of the latter can be found in Ensenada, where 100 hotels and restaurants, the town's major labour supplies, were destroyed by roof collapse due to tephra loading (Ruiz, 2016).

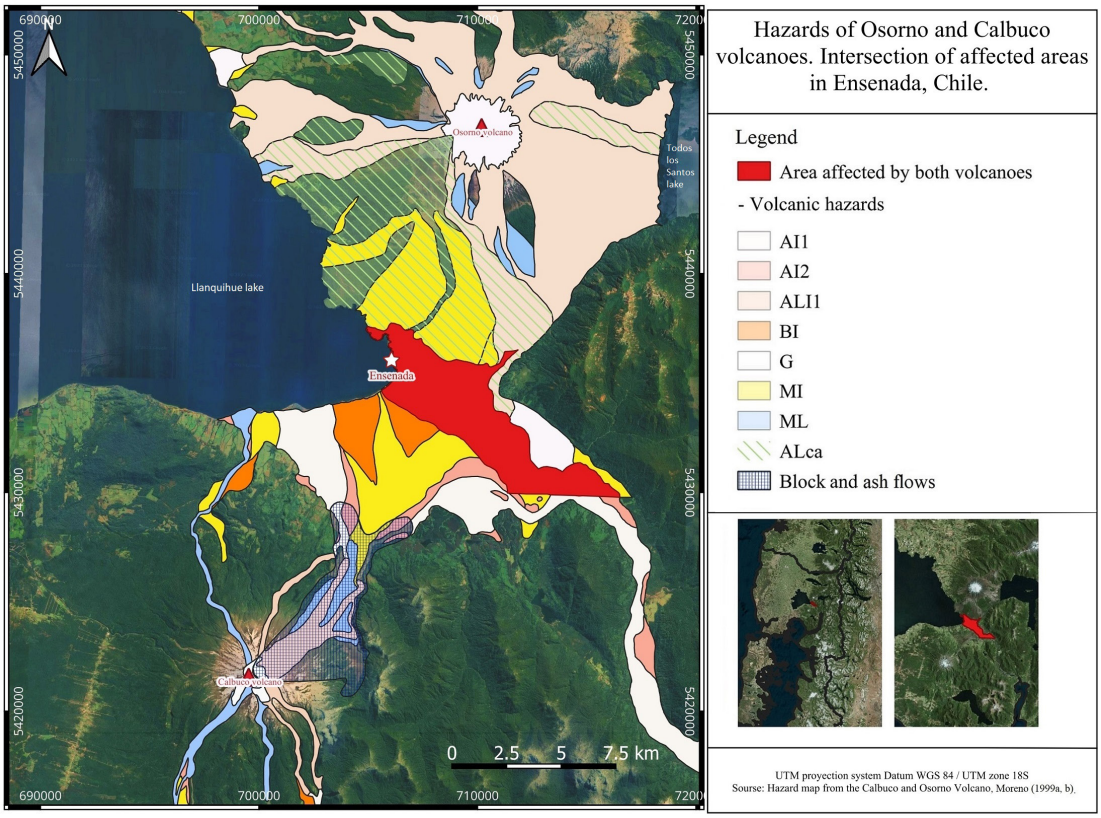

FIG. 3. Intersection of hazard zones from the Osorno (Moreno, 1999a) and Calbuco (Moreno, 1999b) volcanic hazard maps, with the area mostly affected by the 2015 Calbuco eruption painted in red. Labels as in figures 1 and 2.

[4] Onemi. 2015. Gobierno decreta Estado de Excepción Constitucional y Zona de Catástrofe para Llanquihue y Puerto Octay. Disponible en https://www.interior.gob.cl/noticias/2015/04/22/gobierno-ordena-evacuacion-preventiva-por-erupcion-de-volcan-calbuco/

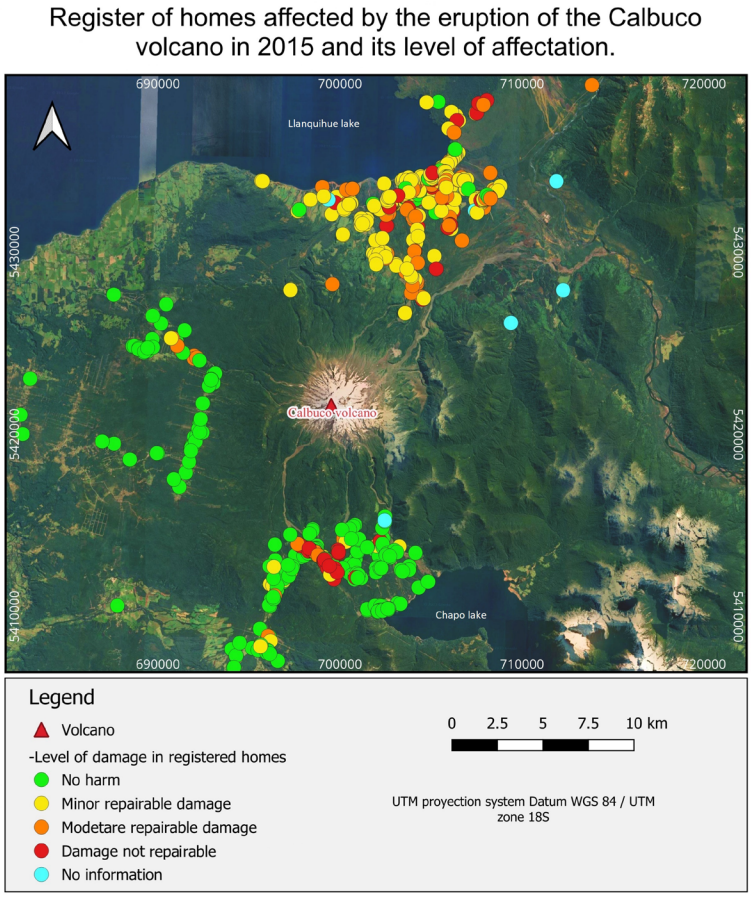

FIG. 4. Location of houses affected by the 2015 Calbuco eruption. Source: Ministry of Housing and Urbanism housing cadastre (Minvu, 2015) and Hayes *et al*. (2019).

TABLE 1. POTENTIAL IMPACTS AT DIFFERENT CIRCULAR DISTANCES AROUND THE TOP OF EACH VOLCANO.

	Calbuco Volcano			**Osorno volcano**		
	10 km	20 km	30 km	10 km	20 km	30 km
N° of affected population	1,593	4,782	50,741	203	2,916	3,369
N° of health services	2	4	13	1	4	3
N° of educational establishments	3	15	77	1	10	11

Source: Authors, based on data obtained in each volcano's specific emergency plan (Onemi, 2018).

4. Material and methods

This research is based on the case study method (Yin, 2003), framed within a qualitative design (Denzin and Lincoln, 2012). The case study method allows the empirical investigation of "a contemporary phenomenon in its actual context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 13). Phenomenon in this sense refers to the simultaneous construction of risks (*i.e*., how they are perceived) and livelihoods that depend on the volcanic landscape. The context points to the human-volcanic system at the local scale (Bachri *et al.,* 2015), where volcanic hazards interact with cultural and economic practices, human-environmental relations, and the production of vulnerabilities materialises.

The methods included the review of documentary sources, such as the legal framework related to emergency management in Chile and the communal emergency management instruments specific to Puerto Varas. In addition, semi-structured interviews (face-to-face and online) were conducted, which implied selecting and recruiting the respondents, drafting the questions and interview guide, defining techniques for this type of interviewing, and analysing the information gathered (Adams, 2015). The sample was delimited on the basis of the theoretical saturation criterion and consisted of 30 participants who were interviewed, including emergency managers from Sernageomin, the Municipality of Puerto Varas, and the Independent Emergency Group of Ensenada (in Spanish, Agrupación de Emergencia Independiente de Ensenada). This allowed us to gather information from each institution about their specific roles, in order to clarify the mechanisms of action, detailing how the current commune system operates in case of emergency. The interview guideline was divided into three main categories (see Supplementary material). The first part focused on collecting the experiences of the most recent Calbuco eruption in 2015, delving into their vision of the volcano before it erupted, during the emergency, and after it. The second part related to technical information about the volcanic hazard from both Calbuco and Osorno volcanoes. The third part addressed the interviewed population's relationship with the institutions and the concrete participation in prevention and information activities.

The semi-structured interviews were conducted in Ensenada in 2021 (Table 2). In doing this, local perceptions of both volcanoes, the institutional framework, and the understanding of hazards were explored. Data collection was randomly distributed, following the patterns of housing damage shown in figure 4, and based on snowball sampling. The information gathered included age range, type of occupation, length of residence, and motivation for living in the area; the latter relevant as it gives context to their different views about the volcanic environment.

The narratives obtained were transcribed, coded, and thematically analysed using the *Atlas.ti* software. Patterns and frequencies were identified in the interviews by focusing on the three different categories specified above. The review of documentary sources on the normative framework, community instruments, and the interviews were triangulated to identify the processes and current governance of volcanic emergency risk in Ensenada. These constitute the framework of official actions that have guided and influenced citizens' behaviour in the face of eruptions. Based on this triangulation, recommendations on how integrating local risk perceptions in volcanic risk management are suggested.

5. Results and discussion

5.1. Multi-scale assessment of disaster risk management in Chile

According to Chilean Law N° 21,364, Senapred's operational framework establishes four coordination structures through committees (Fig. 5), which obey to the principle of scalability since the committees can operate simultaneously. The Disaster Risk Management (DRM) Committees, hereafter referred to as COGRIDs, exercise functions in the different phases of an emergency and at different levels of operation. In the mitigation and preparedness phases, they are convened to approve DRM instruments established by law and to coordinate the necessary instances to develop capacities and resources to strengthen DRM. In the response and recovery phase, according to the severity of the emergency, they are called on to provide technical support.

The main functions of the higher-level, National Committee in the mitigation and preparedness phases are related to the National Policy for Disaster Risk Reduction principles. The Regional Committee is

TABLE 2. SOME CHARACTERISTICS OF THE ENSENADA INTERVIEWEES.

N°	Gender	Age	Occupation	Residence time	Reason of residence
1	Female	36	Householder	Lifetime	Family
2	Male	68	Retired	Lifetime	Family
3	Male	16	Student	Lifetime	Family
4	Female	30	Artisan	2 years	Amenity
5	Male	54	Teacher	6 years	Work
6	Female	15	Student	Lifetime	Family
7	Female	34	Cabin manager	10 years	Family
8	Male	64	Farmworker	36 years	Family
9	Male	68	Cabin manager	40 years	Family/work
10	Female	58	Householder	Lifetime	Family
11	Female	57	Householder	Lifetime	Family
12	Male	55	Holtel worker	Lifetime	Family
13	Male	30	Civil engineer	5 years	Amenity
14	Female	70	Householder	Lifetime	Family
15	Male	65	Cabin manager	Lifetime	Family
16	Male	42	Rancher	Lifetime	Family
17	Female	40	Lodge worker	Lifetime	Family
18	Female	34	Independent	2 years	Amenity
19	Female	46	Minimarket	Lifetime	Family
20	Male	36	Honey trade	4 years	Amenity
21	Male	29	Tourism	3 months	Amenity
22	Female	31	Nurse	1 year	Amenity
23	Male	56	Cabin manager	Lifetime	Family
24	Female	43	Minimarket	Lifetime	Family
25	Male	42	Topographer	1 year and a half	Amenity
26	Male	63	Farmer	Lifetime	Family
27	Female	31	Independent	2 years	Amenity
28	Male	41	Cabin manager	4 years	Work
29	Female	63	Householder	25 years	Family
30	Female	37	Honey trade	1 year	Amenity

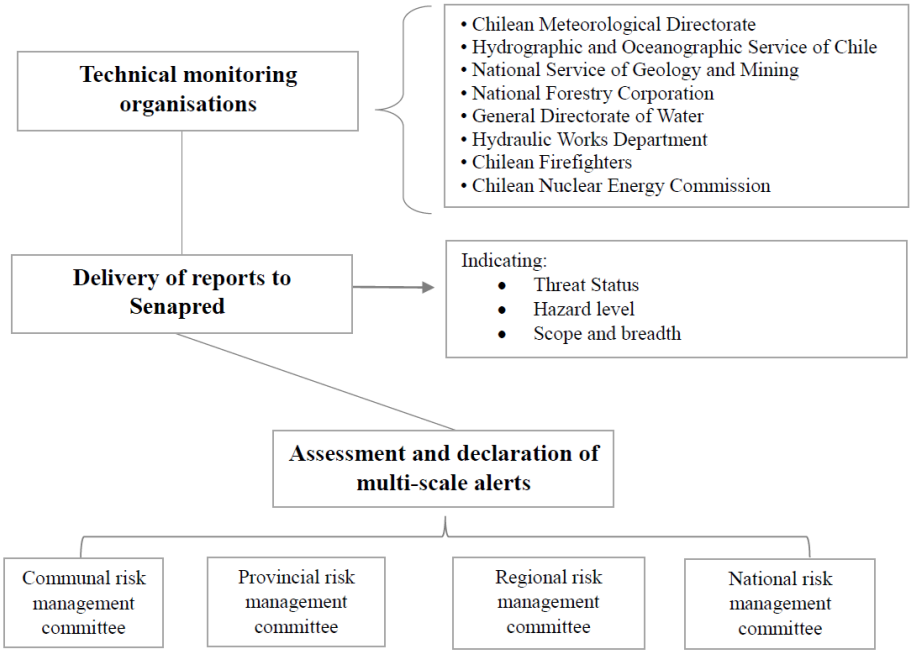

FIG. 5. Diagram of technical organisation and alert flow based on the information published in Senapred Law 21,364.

present in each (16) of the country's regions, and it is in charge of planning and coordinating the System at the regional level, as well as giving recommendations in order to develop capacities and resources to strengthen DRM in this territorial unit. The Provincial Committee is chaired by the figure of the provincial presidential delegate and, together with the official of the Service designated by the regional director, will be permanent members of the committee (Ministerio del Interior y Seguridad Pública, 2021[5]). As for the Communal Committee, the mayor of the commune chairs it and is the committee the entity that must approve both the Communal Plan for Disaster Risk Reduction and the Communal Emergency Plan by mayoral decree, and be in charge of the planning, direction and inter-sectoral coordination of response and recovery actions in the areas affected by an emergency.

In implementing this law, the commune of Puerto Varas constituted the corresponding Communal Committee on 30 May 2022 (Ilustre Municipalidad de Puerto Varas, 2022). DRM plans must consider consonance, harmony and systematicity among them, favouring those of national scope over regional ones and the latter over communal ones. These plans have to especially consider the local, territorial reality and its particular characteristics.

5.1.1. Disaster risk management in Puerto Varas

At the time of writing, the commune of Puerto Varas has a communal emergency plan for the Osorno volcano. This plan is an operational instrument exclusive to the response area, oriented to a single-risk variable and national in scope, aimed at articulating the response of the different agencies involved at a hierarchical level (Onemi, 2018[6]). The objective of the plan is thus to establish the initial response actions in its different operational phases in the event of a volcanic emergency or catastrophe, and to provide protection to the resident and floating populations, together with ensuring the coordinated and efficient functioning of all the agencies involved (Casanello, 2020[7]).

This same communal plan establishes the key community-level agencies, organisations and institutions in case of an eventual eruption at Osorno volcano, as well as the emergency management processes and their respective levels

[5] Ministerio del Interior y Seguridad Pública. 2021. Ley 21.364 Establece el Sistema Nacional de Prevención y Respuesta ante Desastres, sustituye la Oficina Nacional de Emergencia por el Servicio Nacional de prevención y Respuesta ante Desastres, y adecúa normas que indica. Diario Oficial de la República de Chile. https://www.diariooficial.interior.gob.cl/publicaciones/2021/08/07/43022/01/1989445.pdf

[6] Onemi. 2018. Sistema de gestión de emergencias. Mesa por variable: Actividad volcánica - volcán Osorno. https://www.camara.cl/verDoc.aspx?prmTIPO=OFICIOFISCALIZACIONRESPUESTA&prmID=68759&prmNUMERO=185&prmRTE=1623

[7] Casanello, F. 2020. Plan específico Comunal de Emergencia Volcán Osorno. Dirección de seguridad pública y emergencias de la Ilustre Municipalidad de Puerto Varas: 46 p.

of responsibility for coordination and collaboration in the different management stages. Ovdas oversees the regional monitoring phase and the Sernageomin's Technical Office at Puerto Varas is responsible for the communal monitoring. The alert states are governed by those established by Senapred, considering three operational phases: early preventive warning, yellow alert, and red alert.

Once the red alert has been declared, the alert systems are activated, valid for residents and tourists, and the tasks of each of the institutions or bodies present in the territory are specified. The system begins with the activation of the Alert Emergency System (SAE) for mobile phones; the fire brigade has the task of activating the sirens and mobile loudspeakers; Carabineros from the Ensenada and Canutillar stations must alert the population in the interior, rural sectors; the National Forestry Corporation (Conaf) is in charge of alerting the population in tourist and protected areas such as Petrohué, Osorno volcano and Laguna Verde; Navy personnel has to advise the population in the Petrohué sector; and educational establishments should alert the student community through sound equipment and alarms. The evacuation procedures established in the communal plan are foreseen for two possible scenarios:

a. Scenario 1: Staggered preventive evacuation. Valid in case the seismicity at Osorno persists with a gradually increasing pattern. In that case, the technical body (Ovdas-Sernageomin) will increase the technical alert level, with which Senapred Los Lagos (Regional level) may determine the preventive evacuation of the population at risk to a safe area in a to-be-determined perimeter.
b. Scenario 2: Spontaneous evacuation. Valid in the event of a sudden and unexpected eruption. This scenario is possible, as it occurred with the 2015 Calbuco eruption, which showed seismic unrest only a few hours before the eruption. In this scenario, the population evacuates spontaneously to a safe area, aiming to get to the shelter established in the commune (in the Ensenada case, the Liceo Pedro Aguirre Cerda).

On the other hand, within the prevention activities carried out in the commune of Puerto Varas, there was an evacuation drill exercise related to volcanic activity (Osorno in that case). This exercise was carried out on Thursday 17 October 2019. It was called the Osorno Volcano Drill, and covered the communes of Puerto Octay (La Picada, Chapuco, Río Blanco-Coihueco, Aguas Buenas, and Cascadas sectors) and Puerto Varas (Ensenada and Petrohué sectors) (Fuentes, 2019[8]).

The evacuation drill involved conducting several workshops with the local communities. According to Fuentes (2019), the workshops aimed to improve the preparedness of the local population in the case of a volcanic emergency. In the Ensenada sector, the workshop was held on 23 September 2019 and 35 people participated, including community leaders, representatives of local organisations and the private sector. The evacuation target for the exercise was established in coordination with the municipalities of Puerto Octay and Puerto Varas, defining a target of 700 people. Once the drill was over, the official number of people evacuated was 1,251.

This simulation of the Osorno eruption was necessary and positive as it involved, for the first time in a simulation coordinated by Onemi (now Senapred), the population that lives, works, studies or travels in the zones exposed to a future eruption at Osorno volcano (Onemi, 2019[9]). The drill also helped identify deficiencies in the warning systems, such as some mobile devices that did not receive the evacuation alert message due to technical incompatibilities or lack of signal coverage. On the other hand, areas of improvement were also identified, such as creating a register of people who would require additional support in the evacuation process, *e.g.,* elderly, people with disabilities, pregnant women, and electro-dependent people, especially in places difficult to access (Onemi, 2019). In addition, improvements in the signage of evacuation routes should ideally be implemented.

It is worth mentioning that, according to data provided by the Regional Directorate of Senapred Los Lagos, ~2,275 people live in the area that was evacuated during the drill, which means that the percentage of effective participation was ~55%; although the floating population in this area increases the total number of people (Onemi, 2019). The participation of the inhabitants of Ensenada and surroundings, according to the Osorno volcano evacuation drill report, was 450 people.

5.1.2. Disaster risk management in Ensenada

Ensenada has a neighbourhood organisation created by Exempt Decree N° 2899 on June 28, 2010, of the Municipality of Puerto Varas, called

[8] Fuentes, L. 2019. Informe simulacro de evacuación erupción volcán Osorno. Oficina Nacional de Emergencia y Seguridad Pública, Gobierno de Chile: 34 p.
[9] Onemi. 2019. Informe Técnico de Evaluación simulacro erupción del volcán Osorno. Ministerio del Interior y Seguridad Pública, Gobierno de Chile: 6 p.

the Ensenada Independent Emergency Group. This local organisation began to take greater participation after the emergency caused by the Calbuco eruption in April 2015. The organisation aims to generate and organise civil protection actions in the community, planning and coordinating (in conjunction with the Communal Emergency Office) evacuation and protection models during an emergency, as well as integrating and working with community institutions to achieve the group's objectives.

As part of the group's community efforts, an information system was developed focused on joint work and neighbourhood participation. The system consists of the creation of Neighbourhood Emergency Committees (CEV), which follow a hierarchical structure of communication organised through a Committee Chief, a Deputy Chief, and a liaison with the Emergency Group (*e.g.,* Radio Operator and emergency operators). In the pre-emergency stage, the CEV carries out a permanent work of verifying surveys, organising and instructing neighbours on how to act correctly in an emergency, and maintaining active liaison and information networks with the community in a hierarchical order. In an emergency, the CEV has the task of directing and controlling the neighbours in the area and liaising with the Ensenada Independent Emergency group. Among the activities carried out by the group is a cadastre of neighbours. Its objective is to collect information about the evacuation conditions of the community, the specific needs they may have in the different areas of Ensenada, and the meeting points to which they should have access. This cadastre was one of the needs highlighted in the drill held on 17 October 2019.

5.2. Volcanic risk perceptions in Ensenada

5.2.1. Perceptions of risk before, during, and after the 2015 Calbuco eruption

According to our analysis, perceptions of daily life before the April 2015 Calbuco eruption are positive and negative. Positive perception comprises ~75% of the respondents, related to ideas such as volcanoes shape the landscape harmoniously and peacefully, delivering benefits through the volcanic soil. An interviewee in Ensenada says, "for us, it was always a good thing, something that conveyed much tranquillity in the landscape, and we also know that the soils are a product of the eruptions of previous years". On the other hand, the negative view refers to feelings of uncertainty and fear regarding volcanic activity; as one interviewee states, "the volcano itself is something of nature that we cannot control". Although this negative outlook corresponds to ~25% of the interviewees, it should be noted that it corresponds to people who have always lived in the area and may be more aware of the risks related to volcanic activity, as they are also linked to the loss of livelihoods in the event of an eruption.

Perceptions of the 2015 volcanic emergency refer mainly to "the sudden eruption of Calbuco". Regarding the difficulties faced by the inhabitants during the emergency, the main one is related to displacement, considering that "what complicated us the most was that I do not drive, so I did not know how to get to the road with my children", according to a villager who has lived all his life in the area. On the one hand, moving people to a safe area or meeting place has its own limitations, given the heterogeneity in the availability of resources (*e.g.,* ability to mobilise on their own) and the dispersed distribution of families in the rural sectors. Another difficulty was the collapse of telephone lines, which meant that communication was very inefficient. Moreover, overcrowding problems at the time of evacuation were a complication. Although the evacuation was carried out orderly, some inhabitants mentioned that they had difficulties in moving to safe areas due to traffic congestion. Two people mentioned they did not know how to react then, as they had no information on where to go or what to do. "I did not know what to do. I did not know where to go or what could happen", said one interviewee, complementing her account by saying that she had never experienced an eruption and had no information about it.

Perceptions during the eruption also include experiences of impacts on livelihoods (Table 3). People who had animals mention the process of leaving them in the locality at the time of evacuation as a difficulty, describing "what worried us most was that our animals would not be left alone and what food they might have, because we did not know when everything would calm down", and "not being able to see my animals or know what was happening to them when we were away". In the Ensenada area, some families carry out activities related to animal husbandry, which is one of the primary sources of family income. The accumulation of ash is also mentioned as a difficulty, as it caused infrastructure problems, impacted on

TABLE 3. RESPONSES ELICITED CONTAINING ONE OR MORE HARMFUL EFFECTS AS EVIDENCED AFTER THE 2015 CALBUCO ERUPTION EMERGENCY.

Type of damage	% Responses	Description
Animals	~50%	People mentioned damage in relation to animals, loss of livestock, and decrease in animal feed.
Ashes	~75%	People mentioned damage due to ash accumulation, causing structural damage and access difficulties to their homes.
Tourism	~15%	People mentioned the decrease in tourist visits to the area and damage to tourist facilities.

soils, and reduced the availability of vegetation. The latter is consistent with recent research on ecological impacts and disturbances in native forests near the Calbuco volcano (*e.g.,* Bertin *et al.,* 2021; Romero *et al.,* 2023).

Another consequence of the ash accumulation was structural damage, especially to the roofs of houses and sheds; for example, the infrastructure of the local school was severely affected in 2015. Despite the significant material damage documented in the area, the perception of survival outweighs the value of material assets, as "there was no loss of life, which is a fundamental and positive outcome after coping with the emergency". The value of survival over the material goods reflects the cultural and social norms of the affected area, which helps to understand the prioritisation of human life over material possessions, building their perception of volcanic risk substantially on a human dimension.

Finally, all the locals agree on the perceived risk of a future eruption, mentioning that it could occur "at any time, as it has done on other occasions", also pointing to the Osorno volcano, since "either of the two volcanoes and at any time, because Calbuco did not warn us at all". Indeed, according to the interviewees, the damage that occurred was not of significant impact to them. This perception of volcanic activity as a geological phenomenon with which they coexist in the territory stems from their experience in 2015. This aspect directly influences their sense of security when it comes to experiencing an "unexpected" eruption, which is ambivalent. On the one hand, locals allude to the fact that even knowing the risks, they would continue to live in the same place; *e.g.,* "when we came to live here, we were aware of the dangers present in the place where we live, but if we know how to react we can continue to live here" mentions one interviewee, who has lived in Ensenada for two years. On the other hand, other residents developed a negative perception of living in the territory. These perceptions are related to the 2015 eruption, as one resident mentions: "After what happened, we saw that we are always exposed, so I do not feel safe living here", because of the impacts on the activities they carry out in the sector. Another interviewee stresses: "In case of an eruption, I would lose my source of work because, in that case, my bees would not hold out". It can be inferred that the feeling of security is related to knowledge and preparation in volcanic matters, since the accounts that mention the lack of knowledge in volcanism or volcanic emergencies coincide with the feeling of unsafety (Fig. 6). However, after being asked about this issue, the possibility of emigrating because of an eruption is ruled out. This depicts a rootedness to the territory independent of threat situations.

5.2.2. Perceptions of the technical information about volcanoes and relationship with institutions

The local perception of technical information about volcanoes is related to obtaining explanations about volcanic hazards. Among those interviewed, 20 (~67%) responded that they had not received any information on hazards. Some people who know about the damage volcanoes cause did not receive this information from third parties but from lived experiences or their own learning. For those who did receive it, it was through outreach activities they participated in. In this aspect, the sources of information did not only come from institutions, but from schools and workplaces too. As to whether the interviewee knew how to react to a new eruption, either from Calbuco or Osorno, 24 (80%) individuals referred to knowing the obligation to evacuate during

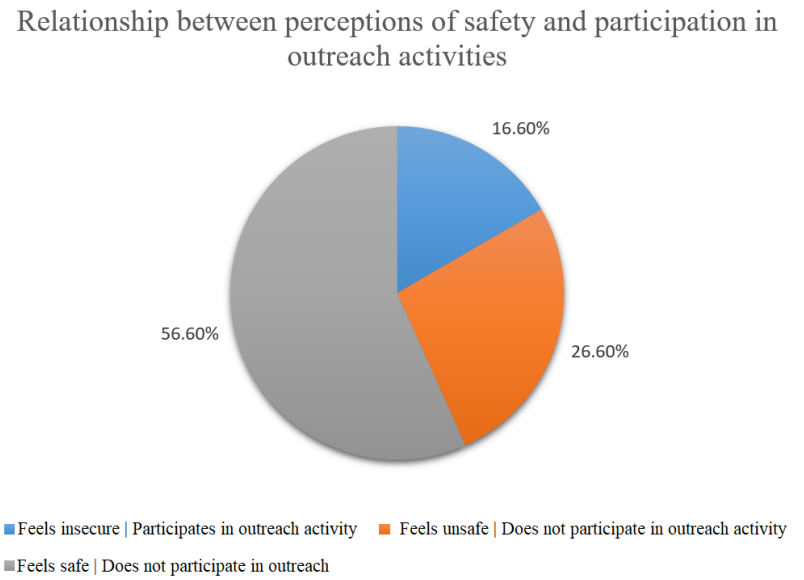

FIG. 6. Relationship between perception of safety and participation in outreach activities related to volcanic events, their consequences, and how to act in response to them.

the emergency. The source of information for this action comes mainly from the experiences of the 2015 eruption.

Some inhabitants are more informed and mention more than two actions in response to a volcanic emergency. For example, one young man says: "You must have an emergency backpack and follow the evacuation routes, have a meeting point with your family and go to a safe place". Regarding the awareness of signals before an eruption, responses include two or more that refer to precursors, as one interviewee mentions: "Volcanoes can give different signals; before an eruption there can be earthquakes, the temperature can change, underground noises can be heard". Inhabitants are generally aware of signals related to seismic activity, underground noises, and fumaroles; however, some of them also refer to the increase in temperature and the unusual behaviour of some animals, mentioning that "the animals start to adopt a different attitude, they perceive things before we do and protect themselves". It is worth noting that, in case of unusual volcanic activity, they would wait for an official alert from the authorities before evacuating or taking decisions.

Knowledge of the warning signs that guide emergency behaviour improves disaster preparedness and response (Leonard *et al.,* 2008). According to some interviewees, evacuation routes are the best-known elements because they are well signposted; meeting points and safe zones, on the contrary, are the least known, a situation attributable to their poor signposting compared to evacuation routes. Eight interviewees mentioned not knowing any of these elements, which we attribute to the fact that they have only recently been living there. We also inquired about the local's knowledge of the emergency instruments developed by the institutions, such as the action plan, the hazard maps, or the evacuation route map. Only three inhabitants mentioned knowing the evacuation route map available for the Osorno volcano.

Recognising the institutional framework in the territories also emerges as a relevant issue in the inhabitants' perceptions. In this sense, Senapred is the most mentioned institution in this question. In the second place comes the Independent Emergency Group of Ensenada and the Emergency Office of the Municipality of Puerto Varas. This situation is due to the several activities that those institutions have developed recently in the area, marking a more significant presence in the community. In the third place is Sernageomin, and lastly, firefighters, as they both participated in prevention and evacuation

activities in 2015. Scientific knowledge related to the institutional roles is increasing. For instance, the year after (2016), the 9th edition of the "Cities on Volcanoes" conference was held in Puerto Varas; there, volcanologists, geographers, sociologists, psychologists, emergency managers, economists, and urban planners around the world met for ~ a week to evaluate the preparedness and management of volcanic crises in cities and densely populated areas. In this context, the experts visited the city of Ensenada. However, according to those interviewed, there is still a gap between the scientists and the population at risk, as many locals did not know about that meeting and did not receive information about the volcanic risk in their territory.

5.3. Recommendations for local volcanic emergency management

From the inhabitants' perceptions, relevant elements and needs related to local risk management emerged during our analysis. These include keeping the population more informed, the improvement of critical infrastructure, and community participation in the exchange of knowledge on active volcanism. We illustrate these three main points below.

5.3.1. Making information on volcanic hazards available to the population

The first need concerns access to volcanological information for the whole territory of Ensenada, as it is located between two active volcanoes (Calbuco and Osorno). Activities have been developed with the community, such as volcanic event preparedness days and evacuation drills, however, according to the interviewees, more attention is given to the Osorno volcano than to the Calbuco volcano, generating a bias in delivering balanced information to the community. The latter is consistent with the findings that various instruments and activities have focused more on Osorno than Calbuco. It is therefore imperative to standardise the development of instruments for both volcanoes equally and design novel cartographic approaches to place the exposed volcanic territory at the centre of multi-hazard mapping.

The second need is related to Ensenada's vocation for tourism. Considering the regional importance of this economic activity, minimal prevention and information conditions concerning volcanic risk were identified, despite the large number of national and international tourists who annually visit the area, increasing the level of exposure of Ensenada to disaster risk. In this sense, it is critical to keep the population and tourists well informed about prevention, action, and response measures for volcanic emergencies, as well as to include and make available to the population hazard maps, evacuation route maps for both volcanoes, and key emergency contacts.

5.3.2. Infrastructure for local disaster risk reduction

The reported infrastructure needs in Ensenada refer mostly to vulnerability conditions at the level of habitability and roads. For instance, some houses on the site, in particular their roofs, do not comply with the requirements for construction in volcanically exposed areas (*e.g.,* materiality, degree of roof pitch). Similarly, there is a need to improve the condition of rural roads and install warning signage regarding eruptions, in order to reduce vulnerability to volcanic risk. By improving the quality of housing materiality, road conditions, and signage, local vulnerability is reduced, thus improving emergency response. Providing clear information on standards for home constructions and/or improvements will reduce damage and vulnerability, and make post-disaster recovery more effective.

Due to the high tourist demand and the variety of services offered, Ensenada has a saturation of tourist signage and a lack of corresponding road signs, which reduces the visibility of evacuation and volcanic risk signs. According to the interviewees, signs indicating evacuation routes and meeting points on Route 225 (Fig. 7) should be much more evident. This aspect makes it challenging to provide clear information, especially for those unfamiliar with the area. Therefore, future measures should be focused on regulating the layout of signs and signage to optimise evacuation information systems in the event of volcanic emergencies.

Another aspect that became evident during the Calbuco eruption in 2015 was the use of the fire alarm to indicate the evacuation of the population. This alarm does not have sufficient range for the entire town, so a more powerful alarm should be installed exclusively for evacuation instructions in volcanic emergencies. It is also important for people to be able to distinguish the warning sound of one type of emergency from another. This requires risk management to disseminate this information in

FIG. 7. Evacuation route signage on Ensenada's main avenue (Route 225). Source: Camila Alegría.

advance so that the association between alarm and eruption can be established and families can make appropriate decisions.

5.3.3. Citizen participation in knowledge exchanges

Direct participation of the community and the diversity of local knowledge is essential to understanding the reality of the territories and their socio-ecological dynamics from the point of view of those who inhabit them (Cronin *et al.,* 2004; Lavigne *et al.,* 2008; Bird *et al.,* 2011; Van Manen *et al.,* 2015; Cadag *et al.,* 2018; Marín *et al.,* 2020; Walshe *et al.,* 2023). In doing so, local knowledge obtained through lived experience or oral transmission and lack of knowledge, both essential to identify the aspects that have been strengthened or relegated, can be explored. In our case study, the interviewees report a perception of weakness in terms of objective knowledge related to volcanism due to a lack of knowledge about some emergency management instruments and institutions, consequence of a low participation in outreach activities. On the other hand, the increase in amenity migration originates new territorial realities, integrating new ways of life and differentiated visions into the existing ones (Zunino *et al.,* 2016). In fact, mountains are one of the most highly valued elements by those who choose to migrate for amenity, which includes the value of the presence of the Osorno and Calbuco volcanoes (Hidalgo *et al.,* 2014). However, many of these new ideas about living in pristine landscapes may ignore Ensenada's social, environmental, and volcanic characteristics.

Regarding local knowledge, this is mainly based on identifying the effects of past experiences, which contributes to the self-recognition of vulnerabilities for the inhabitants of Ensenada. These records constitute a primary source of vulnerability knowledge so work

guidelines can be established with the community, strengthening the relationship between institutions and locals, as well as equalising and improving knowledge on issues related to both volcanoes. In this sense, the inclusion of the community should be expressed in exchange of knowledge and territorial needs. Local disaster risk management could be strengthened by rethinking the contingency as a process that involves a multiplicity of actors (Vergara-Pinto, 2021), and that requires the design of a plan to readjust daily dynamics and monitor the recovery of the communities.

5.4. Insights for integrating local risk perceptions into disaster risk management

Our findings allow us to identify, in the first instance, the functioning of the Chilean institutions at the national, community, and local levels. The current context of change in the management system favours a period of latency due to the progressive creation and adaptation of services to the new law. This change also allows civil protection institutions to develop a preventive rather than a reactive approach. The lack of preparation of the local communities reflects the precariousness of preventive actions and the correct bi-directional exchange of knowledge, which are the basis of an adequate adaptation strategy to avoid socio-natural disasters (Romero and Romero, 2015). On the other hand, the role of Senapred in conducting the Technical and Executive Secretariat of the Committees at the national, regional and provincial levels is a step forward in the interdisciplinary and inter-sectoral approach to disaster risk management, bringing new perspectives on the impacts and response to emergencies. However, integrating local perspectives in risk management is still pending in the new law.

The work carried out by the Ensenada Independent Emergency Group gains relevance due to the civic nature of its organisation, emphasising the coordination work with the neighbours and the constant motivation to make improvements for the community. It also stands out for being a group with direct community participation, giving roles and tasks to the residents; although a more collaborative and constant work with the municipality could further enhance the group's work and the community's bond. In this sense, the territory of Ensenada complies with socio-cultural conditions to foster greater community involvement in volcanic risk management. This is consistent with studies of community involvement in risk management in Latin America, particularly in the Colombian and Ecuadorian Andes (*e.g.,* Mothes *et al.,* 2015; Calvache *et al.,* 2021), which provide relevant avenues to explore the interaction between official and unofficial institutions, including local communities.

In terms of local perception of volcanic risk in Ensenada, the experience of the Calbuco 2015 eruption is a concrete reminder to both institutions and locals of the threats of living in volcanic territories, especially because no significant warnings prior to an eruptive event are a possibility. However, in the 2015 case the emergency conditions were favourable only to cause structural damage, so the reconstruction work left little or no change to existing livelihood systems. For this reason, when the idea of moving away from the endangered area was raised, the answer was entirely negative. This situation can be understood if it is considered the habit of living in a volcanic space and a rural community that produces conditions that increase the sense of socio-territorial attachment, such as productive practices, social relationships, different perceptions of rural and urban life, and/or the sense of time (Vergara-Pinto, 2021; Sandoval-Díaz *et al.,* 2022). These conjugated elements influence the perception of the volcanic region as a place of family tradition, which makes inhabitants unable to imagine life in another place, much less in urban territories. In immaterial terms, the representations of the significance of surviving eruptions, added to visualising the transformations and restoration of nature over the years, are also deeply intertwined with volcanic memory, deepening the sense of attachment to the place and the sense of belonging to the volcanic landscape (Vergara-Pinto and Marín, 2023).

There are areas for improvement related to the lack of information of a more technical nature or relationship with the institutions. This situation coincides with reduced participation in prevention activities and limited knowledge of emergency plans. Risk communication fails when the needs and knowledge of the inhabitants are not known (Scolobig *et al.,* 2015; García and Méndez-Fajury, 2018). There are specific activities to remedy this; for individuals to have appropriate knowledge on volcanic phenomena and associated risks, it is

necessary to generate long-term dialogic processes where citizens are challenged with information about their territory and their daily lives, so they can be both participants and producers of the messages that will circulate (Calvache *et al*., 2019). Furthermore, volcanic products and landscapes represent a source of geoheritage or material memory of the Earth (Brierley, 2010). When well preserved and easily accessible, volcanic outcrops can be used to share hazard knowledge between volcanologists and local communities through geoeducation techniques, increasing volcanic risk mitigation (Sánchez *et al.,* in prep).

In the Ensenada area, the inhabitants perceive the risk of facing activity from either Calbuco or Osorno. These volcanoes' different eruptive histories are imprinted in how future eruptions could be and what emergency management may look like. This antecedent shows how perceptions of past eruptions, which are also part of a social memory (Wilson, 2015; Murti, 2021; Ojeda-Rosero and López-Vázquez, 2023) and 'stratified' in people's memories (Vergara-Pinto and Marín, 2023), constitute a source for investigating possible social predispositions in the face of scenarios that are unknown or unimaginable to the population (Vergara-Pinto and Romero, 2023). For example, the current population of Ensenada has not faced an eruption of the Osorno volcano for 188 years, which means that they do not have an experiential reference to imagine what a future eruption might look like and how they should respond to it. On the other hand, the multiple eruptions of the Calbuco volcano provide different scenarios and probabilities about its future behaviour. The study of local perceptions of risk, therefore, contributes to recognising how people make sense of volcanic phenomena and hazards, where risk management can join in undertaking actions logical and reasonable for the exposed communities.

Regarding strategic directions, recognising and incorporating local insights and knowledge into mitigation, management, and recovery plans remains a major challenge. The guidelines illustrated in this research aim to articulate action plans contextualised to the reality of the town of Ensenada. Although local knowledge, accumulated and circulated in communities and territories, multiplies and becomes crucial in the in-situ management of socio-natural risks, it has yet to be robustly integrated into disaster risk reduction instruments and regulations (Tironi and Molina, 2019). In summary, this research provides the following considerations for integrating local risk perceptions into disaster risk management in eruption-prone areas such as Ensenada:

1. The experience of volcanic eruptions reveals the positive and negative aspects of the emergency.
2. Local perspectives differ from the institutional ones due to the different ways of inhabiting the territories.
3. Improvements identified by the local inhabitants can be translated into local and institutional management and direct knowledge towards the most urgent needs.
4. The collection of local knowledge allows dialogue between the population and the institutions to develop joint actions applicable to the territories.
5. The development instances of citizen participation in scientific knowledge allows the reciprocity of knowledge between actors.

6. Conclusion

From a socio-cultural approach, volcanic risk is a field that collects multiple experiences, values, and knowledge from different perspectives. In this sense, the Ensenada case study is illustrative about the role of local perceptions of risk in that they contain people's ideas that influence the development of self-protection and prevention actions to reduce the exposure of their territory in case of future eruptions. The current change in the Chilean emergency system is an opportunity to integrate local risk perceptions into disaster preparedness strategies in response to volcanic eruptions, as well as an instance for strengthening the relationship between the technical and scientific institutions and the community.

In understanding and assessing perceptions of volcanic risk, combining interdisciplinary geographical and anthropological approaches can contribute to developing more sophisticated frameworks to improve this aspect. By considering the geographical setting of the territories and the cultural setting expressed in the communities' attachment to hazardous spaces, socio-cultural research identifies how communities have historically coped with socio-natural disasters and how their perceptions and knowledge can be leveraged to develop more effective disaster response plans. In this sense, this article acknowledges the relevance of local perceptions and supports the empowerment of communities to take a more active

role in volcanic disaster prevention, preparedness, and management in their territories.

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Supplementary material

Interview guideline on volcanic risk perception, Ensenada

Before the eruption

1. Have you experienced an eruption of the Calbuco volcano? What was your experience during the 2015 eruption?
2. What did you think of the volcano before the 2015 eruption?

During the eruption

3. What difficulties did you encounter during the emergency caused by the Calbuco eruption?
4. How do you think the management of the emergency agencies was during the 2015 eruption?

After the eruption

5. How were you affected and did the rash harm you or a family member?
6. Have you seen any changes since the last eruption? In terms of, for example, infrastructure, signage, etc.
7. Were you able to maintain your daily activities after the eruption or did you have to change them (*e.g.*, change of economic activity)?
8. Do you think the volcano will erupt again? Why?

Perception of volcanic risk

9. Do you feel safe living in this area?
10. Do you feel you live in the same way as before the last eruption, yes, no, why?

Information on technical knowledge of volcanism

11. Have they explained to you the damage that the volcano can cause?
12. Do you know how to react to a new eruption, and where did you get this information?
13. Do you know the signals that the volcano emits before an eruption? What kind of signals from the volcano would alert you (underground noises, fumaroles, earthquakes, etc.)?
14. Do you know the evacuation routes in your area, meeting points or safe zones?
15. Do you know the different dangers of the Calbuco volcano and the Osorno volcano?
16. Do you know the action plan, hazard map, evacuation routes, etc., and do you think it is easy to understand?

Institutionality-related activities

17. Do you know which institution you should contact to obtain information about the volcano's activity?
18. Have you or anyone close to you participated in any preventive dissemination day organised by Onemi, Sernageomin, municipality, etc.? How did you find out about these?