Changing hazard awareness over two decades: the case of Furnas, São Miguel (Azores)

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Abstract: Furnas (*c.* 1500 inhabitants) lies within the caldera of Furnas volcano on the island of São Miguel (Azores) and has the potential to expose its inhabitants to multiple hazards (e.g. landslides, earthquakes, volcanic eruptions and degassing). The present population has never experienced a volcanic eruption or a major earthquake, although the catalogue records six eruptions, sub-Plinian in style, over the last 2 kyr. Today, the area experiences strong fumarolic activity. In the case of an eruption, early evacuation would be necessary to prevent inhabitants from being trapped within the caldera. An awareness of potential threats and knowledge of what to do in the case of an emergency would assist in evacuation. In this paper, inhabitants' awareness of volcanic and seismic threats in 2017 is compared with that revealed in a similar study completed more than two decades ago. It is concluded that whereas awareness of earthquakes and the dangers posed by volcanic gas discharge has increased, knowledge of the threat of volcanic eruptions and the need to prepare for possible evacuation has not. Research suggests that the changing awareness is related to effective collaboration that has developed between the regional government, through its civil protection authorities and scientists, and the people of Furnas.

Furnas, with a population of 1439 (SREA 2012), is located within the active caldera of Furnas, the easternmost volcano of São Miguel island in the Azores (Dibben and Chester 1999). The village (Fig. 1) is exposed to multiple hazards and its setting within the caldera severely limits the number of exit routes that people could take in the event of an emergency (Andersson *et al.* 2016). The village (207 m above sea level (asl)) is less than 2 km from the crater lake of Lagoa das Furnas (359 m asl). Lagoa das Furnas covers an area of *c.*1.82 km^2 and has a total volume of *c.* 13×10^6 m^3 (Andersson *et al.* 2016). The altitude difference between the lake and the village exposes the village to floods. The village and the lake are inside the caldera, and are surrounded by steep slopes that are formed from poorly consolidated material together with massive lava-flow horizons, a geology which is conducive to the generation of landslides and rockfalls, especially after heavy rain and/or as a consequence of seismicity (Dibben and Chester 1999).

Most of the population of Furnas has never experienced a high-magnitude earthquake and no inhabitant has experienced an eruption but the Furnas area is subject to low-level seismicity and sporadic low-magnitude seismic swarms (Marques *et al.* 2005; Viveiros *et al.* 2014), such as the one that affected the area between 2005 and 2008 (Marques *et al.* 2005; Viveiros *et al.* 2016). In the last 5 kyr, 10 explosive trachytic eruptions measured as having a Volcanic Explosivity Index (VEI) of 3–4 have occurred on Furnas (Cole *et al.* 1999) and, of these,

From: Marotta, E., D'Auria, L., Zaniboni, F. and Nave, R. (eds) *Volcanic Island: from Hazard Assessment to Risk Mitigation*. Geological Society, London, Special Publications, **519**,
https://doi.org/10.1144/SP519-2020-120

Fig. 1. The location of the Azores, São Miguel and Furnas volcano (modified from Duncan *et al.* 2015, fig. 11.1, p. 148).

two have occurred since the beginning of the fifteenth century. The last eruption occurred in AD 1630, was sub-Plinian in style, and produced widespread tephra-fall, pyroclastic flows and surges, floods, and landslides (Moore 1990; Cole *et al.* 1995, 1999; Guest *et al.* 1999; Wallenstein *et al.* 2005, 2015; Queiroz *et al.* 2008).

This paper explores Furnas residents' attitudes of risk and the ways in which these have evolved over the past 20 years. This is based on comparing attitudes surveyed in 1994 (Dibben 1999; Dibben and Chester 1999) with those revealed in a 2017 study (Lotteri 2020) and which are reported in this paper. Processing the results of the surveys involved thematic analysis, which is a flexible methodology that facilitates a search for patterns or themes within data (Braun and Clarke 2006). This approach assisted in the assessment of attitudes to risk that were present among the inhabitants of São Miguel at the time of the surveys in 1994 and 2017. The themes that emerge are presented below under the following headings: population and hazard response; volcano-related awareness and preparedness for a future eruption; volcanic gases: awareness and preparedness; risk perception; land attachment; and livelihood, resources, self-protection and resilience.

Understanding attitudes towards risk is important in assessing a community's preparedness to cope when affected by extreme events, especially ones in which physical processes have not been sufficiently severe to produce major losses for many years (e.g. Dominey-Howes and Minos-Minopoulos 2004; Perry and Godchaux 2005). Furnas fits these criteria because the most recent earthquake in the area, with an intensity of VIII (EMS-98) and a magnitude of 5.6, was in 1952 and the last volcanic eruption was in 1630 (Gaspar *et al.* 2015). Perry and Godchaux (2005) stress the complexity of living in areas exposed to extreme volcanic events, pointing out that many people do not understand that many volcanoes have long repose periods between eruptions. Inhabitants living on volcanoes often develop an awareness that such locations are 'part of a supportive, nurturing environment rather than a threatening one' (Perry and Godchaux 2005, p. 184).

Furnas volcano fits Perry and Godchaux's (2005) description of a welcoming environment and appears as a fertile scenically attractive area. This is because of a combination of volcanic soils, which have been brought into productive use by centuries of careful land management, and a humid temperate climate. Yet, hydrothermal features of volcanism are present within the landscape and, indeed, within the village itself in the form of fumaroles, CO_2-rich cold springs, thermal springs and emissions of steam (Viveiros *et al.* 2015). In volcanic environments there are studies of population awareness, not only during periods of quiescence (Perry 1990; Barberi *et al.* 2008; Ricci *et al.* 2013) but also after a crisis (Saarinen and Sell 1985; Gaillard 2008). Broadly similar research has been carried out in environments affected by earthquakes (Armas 2006; Santos-Reyes

et al. 2014), hurricanes, floods and landslides (Morss and Hayden 2010; Bustillos Ardaya *et al.* 2017; Hernández-Moreno and Alcántara-Ayala 2017). Longitudinal studies have also been published that examine the evolution of awareness over time (Siegrist 2014; Bird *et al.* 2020). Trumbo *et al.* (2014), for example, examined the risk perception of participants exposed to hurricanes immediately after an event and a few years later, while Johnston *et al.* (1999) provide a rare insight by comparing post-event responses with similar data obtained prior to an eruption of Ruapehu volcano in New Zealand. Our research presents a longitudinal study covering the evolution of volcanic and earthquake awareness in the village of Furnas over a time interval of slightly over 20 years when there has been only a minor seismic crisis between 2005 and 2008 but no major earthquake or eruption. It is our contention that the evolution of awareness amongst participants is predominantly linked to education and the acquisition of knowledge, rather than as a result of any direct experience.

Geology of Furnas volcano

Furnas volcano (Fig. 2) comprises a caldera complex with two 'nested calderas' (Silva *et al.* 2015, p. 197):

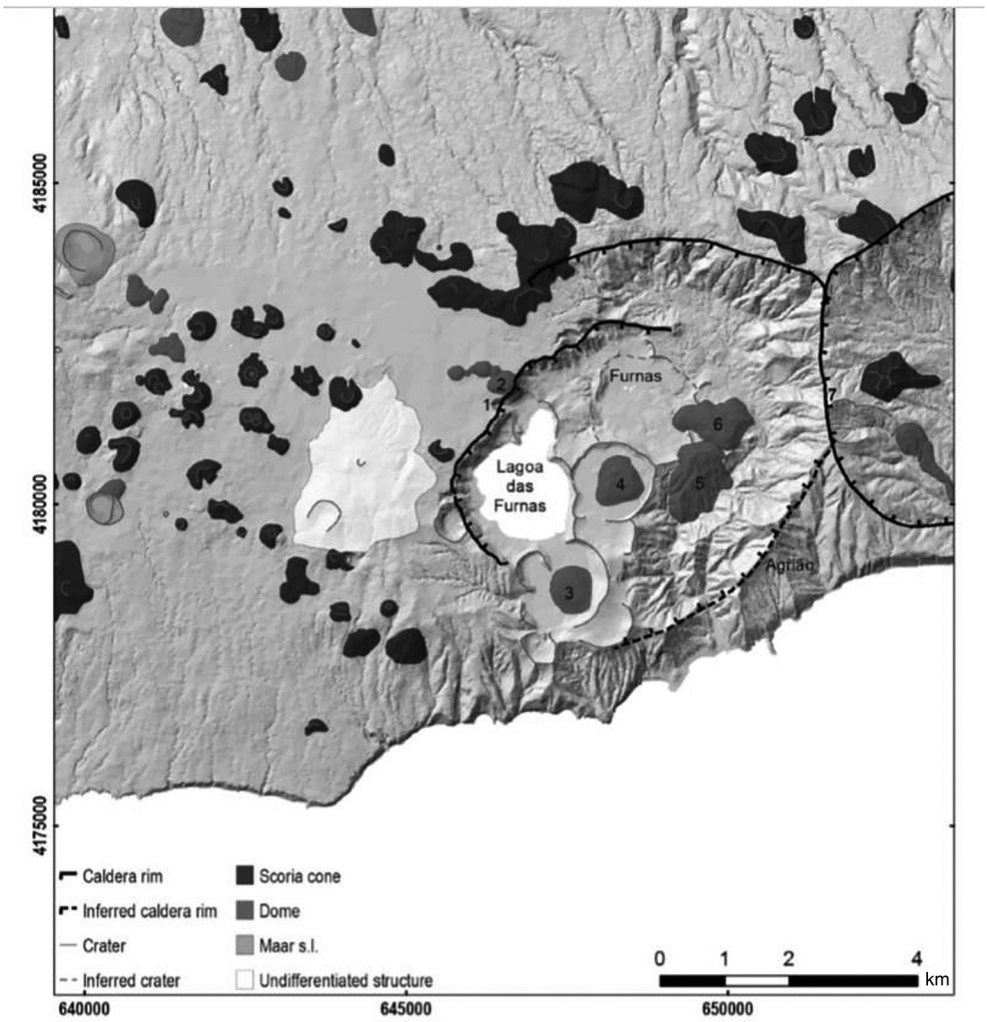

Fig. 2. Volcanic and tectonic structures of Furnas: 1, Salto da 525 Inglesa; 2, Pico do Ferro; 3, AD 1630 dome; 4, Gaspar AD 1439–44; 5, Pico 526 Marconas; 6, Pico das Caldeiras; 7, Pico do Canario (after Guest *et al.* 2015, fig. 9.2, p. 126, various authors).

the older one is *c.* 30 ka (Guest *et al.* 1999; Silva *et al.* 2015) and measures 7 × 5.5 km (Carmo *et al.* 2015), and the younger (inner) caldera is 12–10 ka and is 4.5 × 3.5 km in size (Silva *et al.* 2015). The most recent stratigraphic interpretation (Guest *et al.* 2015, p. 127) suggests that the volcano has a 'lava-built basement' topped by explosive deposits and is around 100 kyr old (Cole *et al.* 1999). According to Guest *et al.* (2015), the principal caldera was formed after the most significant of all its eruptions, which occurred at *c.* 30 ka. This eruption was followed by an infilling period (Guest *et al.* 1999) until 11 kyr ago, when the inner caldera collapsed (Guest *et al.* 2015). In the last 5 kyr, 10 eruptions, sub-Plinian in style, have been recorded at Furnas, the latest being in 1630 (Guest *et al.* 1999). Today, activity is mostly associated with CO_2 soil degassing (Viveiros *et al.* 2015).

Furnas: a European Laboratory volcano

The first initiatives regarding volcanic hazard evaluation, management and community perception in the Azores were triggered by the European Laboratory volcanoes project. In 1993, Furnas volcano was selected by the Research and Development Environment Programme CEG-DGXII of the Commission for the European Communities (now the European Union) as one of their 'laboratory volcanoes'. This research involved researchers from most EU countries including Portugal. Between 1993 and 1996, Furnas volcano became the subject of a project that investigated geological, petrological, geochemical, geophysical, geothermal and potential threats posed by the volcano (Guest *et al.* 2015). Within these projects, one in 1994 involved interviewing inhabitants of Furnas about their awareness of threats posed by environmental extremes (Dibben 1999). At the time, there was neither permanent monitoring equipment in place nor emergency planning for Furnas or other settlements within the vicinity of the volcano (Dibben 1999), and a civil protection infrastructure had only been present across São Miguel for a short time.

Geological risks and civil protection

Three institutions have been pivotal in raising public awareness of volcanic hazards in Furnas: the Serviço Regional de Proteção Civil e Bombeiros dos Açores (SRPCBA), Centro de Informação e Vigilância Sismovulcânica dos Açores (CIVISA) and Centro de Vulcanologia e Avaliação de Riscos Geológicos (CVARG), which was established in 1997 as a multidisciplinary autonomous research unit affiliated to the Department of Geosciences within the University of the Azores.

In 1999, the Azores Regional Government funded the Azores Civil Protection and Fire-fighting Service (SRPCBA), bringing together the organizations responsible for civil protection and firefighting. SRPCBA has a remit and funding to guide, coordinate and supervise civil protection and rescue activities across the islands of the archipelago. In an emergency, it would take a leading role in coordinating responses and organizing transport (Cabral 2015). Further initiatives are aimed at prevention, and the counselling and training of inhabitants with trial earthquake evacuations, and, thus, SRPCBA has developed into an organization with terms of reference that include educating the population about the hazards they face from extreme meteorological and geophysical events (SRPCBA 2020). Since 2016, CVARG has been known as IVAR (Instituto de Investigação em Vulcanologia e Avaliação de Riscos: http://www.ivar.azores.gov.pt/civisa/Paginas/homeCIVISA.aspx).

Methodology and data collection

This paper focuses on the changing attitudes towards the threats posed by environmental extremes in Furnas, especially those posed by volcanoes and earthquakes, over a period of two decades. It compares findings from the 1994 research project conducted by Dibben (1999) with those of a survey conducted in 2017 (Lotteri 2020). Thematic analysis was applied in order to compare attitudes in 2017 with those of 1994.

Dibben's (1999) survey focused on hazard awareness in Furnas. In his study, 50 participants were interviewed with questions focusing on: (1) the duration of residence and the reason(s) for moving to the village; (2) attitudes towards the village as a place to live; (3) perceptions of volcanic threats and other environmental extremes; (4) disaster preparedness; and (5) attitudes towards mitigation measures (Dibben and Chester 1999). The results showed hazard awareness to be poor and inaccurate (Dibben and Chester 1999; Wallenstein *et al.* 2015).

The 2017 study replicates the interview questions that were used in 1994 by means of a schematic set of questions and semi-structured interviews. This approach focuses on understanding the behaviour of members of the public 'without placing any *a priori* categorisation that may limit the field of inquiry' (Fontana and Frey 1994, p. 366), and has been applied in studies seeking to assess the awareness and perceptions of residents living in hazardous environments (Bird 2009). Dibben's (1999) original questions were used (without amendment) to enable direct comparison to be made between 1994 and 2017. The questions were translated into Portuguese, and were used to interview participants between

April and June 2017. The interview sheet included both English and Portuguese language versions in order to demonstrate the accuracy of translation, and to assure trust between the authors and the participants. A graduate research assistant, who knew local dialects and understood São Miguel's culture, was hired for this purpose. His presence greatly facilitated first contact with the participants.

Potential participants were approached in the following public places in Furnas village: bars, cash machines, shops and parks. After the initial engagement, using the language preferred by the participant (i.e. either English or Portuguese), the interviewers introduced themselves and, if the person agreed, they were invited to sign a consent form that was drawn up in compliance with protocols published by Liverpool Hope University. Each participant was assigned a sequential number: for example, the first participant interviewed was identified as Participant 1 and the 10th as Participant 10; and two interview sheets were used, one for the participant and the other for the interviewer. According to the participants' preferences, the questions could be read either by the author or by the participant directly but only one participant chose to read the questions. When the interview was carried out in Portuguese, the researcher waited for her assistant to translate the answers, which were then noted; however, when the interview was conducted in English, the researcher directly recorded the answers. In total, 54 participants were approached to provide numbers similar to those approached in 1994, and no further attempt was made to match age, gender and level of education. Table 1 shows the age, gender and level of education of the participants. Decisions were made to exclude people under the age of 18 and to reach a target of 50 interviewees so that results could be compared with those obtained in 1994.

Results

This section presents an analysis and comparison of the results of Dibben's 1994 research with those of the 2017 survey. Techniques of analysis were based primarily on descriptive statistics and the qualitative assessment of participants' narratives using thematic analysis. Thematic analysis is a well-established method of analysis and presentation of results within qualitative research (Braun and Clarke 2006). This research analysed the interviews following a 'participant determined' approach, in which themes emerged from the participant responses (Dunn 2000; Tuckett 2005). Key results are presented under the following headings: population and hazard response; volcano-related awareness and preparedness for a future eruption; volcanic gases: awareness and preparedness; risk perception; land attachment; and livelihood, resources, self-protection and resilience.

Population and hazard response

According to Pfeifer (2017), when people estimate the probability of a disaster, the more memorable the occasion 'the higher the degree of belief people will have in the recurrence of similar events' (p. 4). The literature on hazard and risk perception takes into account the significance of the threat in order to evaluate the extent to which it affects the minds of inhabitants who are exposed. A well-established way in which to investigate how a threat impinges on the minds of participants is to ask them to list three positive and three negative features of living within their community (e.g. Barberi *et al.* 2008). Table 2 summarizes differences in hazard cognition in 1994 and 2017 by examining what participants believed to be positive aspects of living within the community of Furnas.

Participants mentioned natural beauty as a positive reason for living in Furnas in both the 1994 and 2017 surveys. Natural beauty represents a support to the local economy in the eyes of both the 1994 and 2017 participants, and this attracts visitors to the village. The most notable natural attractions of São Miguel are its three volcanoes and their lakes, as emphasized in tourist brochures and advertisements. Furnas is one of the villages most frequently mentioned because of its thermal springs and fumarole fields, attracting both tourists and local visitors (Wallenstein *et al.* 2015). Attractive features of the landscape are the result of volcanic activity but results from the survey indicate that scenic quality is

Table 1. *Characteristics of the 54 participants interviewed in 2017*

Furnas: age cohort	Age	Gender	Level of education*
18–24: *c.* 7%	18–24: *c.* 13%	Male: 62%	Primary (ages 6–14): *c.* 26%
25–45: *c.* 28%	25–45: *c.* 50%	Female: 38%	Secondary (ages 15–17): *c.* 55%
46–64: *c.* 26%	46–64: *c.* 22%		Tertiary (i.e. university): *c.* 13%
Over 65: *c.* 15%	Over 65: *c.* 15%		

*10% of the participants did not declare their level of educational attainment.

Table 2. *Comparison of responses to the 1994 and 2017 surveys with respect to the perceived positive aspects of living in Furnas village*

Categories 1994	$n = 50$	Categories 2017	$n = 54$
Natural beauty of the area, the closeness to nature and the economic prosperity that results from these characteristics	58%	Natural beauty	37%
It is good to live here	20%	It is good to live here	6%
Feel at home in land of my ancestors	14%	Quality of life, the peaceful and relaxing atmosphere	30%
Social life and a feeling of community	2%	Social life and a feeling of community	4%
Other	6%	The economic prosperity and low violence	19%
		Other	4%

perceived as being part of a 'nurturing environment', a view that is shared with other communities living in the shadow of volcanoes and from which there have been no eruptions for a long time (Davis *et al.* 2005; Barberi *et al.* 2008). Negative aspects of living in Furnas are summarized in Table 3.

Participants who mentioned hazards as a negative aspect of residing in Furnas accounted for 7% of participants in 1994 and 6% in 2017. The lack of employment was on the minds of many participants in both 1994 and 2017 but there were more in 2017. Hazard awareness did not change greatly over 23 years and the percentage of people mentioning this feature is very low. The inhabitants of Furnas live inside a caldera and downplayed risk, and this attitude is commonplace amongst people living in areas exposed to high levels of risk because of what is termed 'optimism bias' (Gardner and Stern 2002, in Perlaviciute *et al.* 2017, p. 2). Optimism bias may lead to underestimating the probability of a disaster and/or downplaying the extent of its consequences (Pfeifer 2017). This lack of accurate perception may also be explained by the presence of more visible daily issues within a community's consciousness (Davis *et al.* 2005; Barberi *et al.* 2008). Despite hydrothermal features of volcanism being present both near to the centre of the village and in its surroundings, the perception of the risk of an eruption is low (Viveiros *et al.* 2015). In 1994, participants thought that 'an eruption had not happened in their lifetime implying that it was unlikely to happen in the future' (Dibben and Chester 1999). Similarly, in 2017, Participant 1's response is helpful in providing a reason for complacency, 'the volcano is always the same (as) it was 40 years ago. (Its) landscape has never changed and nothing (has) ever happened'. In other words, the experience of Participant 1 is that nothing has changed during his or her whole life, so he or she does not expect any changes in the future. This provides an example of what Perry and Godchaux (2005) claim is a need for non-scientists to articulate the opinion that most volcanoes have long repose periods between eruptions and that an eruption will probably will not affect them.

Volcano-related awareness and preparedness for a future eruption

Works such as Dibben and Chester (1999) and Wallenstein *et al.* (2015) point out that early evacuation of Furnas may be the most appropriate action to take in order to avoid a catastrophe in the event of a volcanic emergency. Bird and Dominey-Howes (2008) point out how public response to evacuation orders will be effective if orders are: clear and accurate;

Table 3. *Perceived negative aspects of living in Furnas*

Categories 1994	$n = 50$	Categories 2017	$n = 54$
No problems	57%	No disadvantages	36%
No jobs for the young generation	10%	Unemployment	42%
Tourists and outsiders (foreigners)	9%	Parking during tourist season	2%
Changes in the traditions of the community	9%	Isolation from the rest of the island	9%
Environmental risks	7%	Environmental risks	6%
Price of commodities	6%	Weather	2%
Drug abuse and aggressive behaviour	7%	Declined to answer	6%

The sum does not round to 100% because participants provided multiple answers.

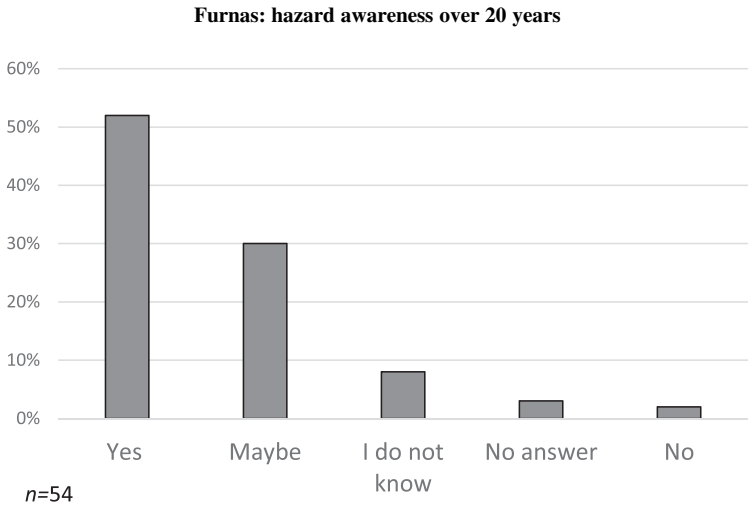

Fig. 3. Participants' level of awareness regarding warnings before eruption in 2017.

timely; occur in the context of an established emergency infrastructure; and when there is both public understanding and an accurate perception of hazard and risk (Dominey-Howes and Minos-Minopoulos 2004; Johnston *et al.* 2005; Bird and Dominey-Howes 2008 and references therein). The public awareness and perception of threats is, thus, a fundamental element in developing appropriate responses to future emergencies. Despite Furnas being extremely exposed, the 1994 survey showed an inappropriate level of awareness with regard to earthquake and volcanic risks (Dibben 1999).

All the 1994 participants knew that Furnas was located within a volcanic caldera, yet they did not see this as being a major concern and were genuinely shocked when asked to think about a future eruption (Dibben and Chester 1999). Furthermore, in 1994, participants did not believe that they would have any warning should an emergency occur. Figure 3 records participants' responses in 2017.

In 2017, more than half of the participants thought that there would be a warning before an eruption and only 2% responded that this would not be the case, and, in this respect, there is clearly an improvement over the situation in 1994 when the principal response was that there would not be any warning. Some participants provided additional information stating that they had been informed that the volcano was monitored. Nevertheless, approximately 40% of the 2017 participants did not provide a clear response, preferring to state 'I do not know' or 'maybe'; such answers being indicative of a process of communication between stakeholders and the population that is still very much in progress. In addition, in 1994 there was no permanent monitoring equipment in place (Dibben 1999), whereas in 2017 there was a monitoring system in place, and this 'visibility' may explain the differences between 1994 and 2017. A further element suggesting an ongoing process of communication is that participants in 1994 thought that nobody in the village could give them advice about volcanic hazards, whereas in 2017 38% of participants knew where to access information (Table 4).

Amongst participants answering a clear 'yes' or 'no' ($n = 30$), 70% noted that information about volcanic activity was well distributed, whereas 30% thought it was not. Amongst the 31% ($n = 17$) who did not provide a clear 'yes' or a clear 'no' answer, rather an 'I do not know', 70% replied that they would either seek information from CIVISA (the Centre for Information and Seismovolcanic Surveillance of the Azores) or from the University of the Azores; these results imply that the participants knew that information was available. An additional feature was that in 2017 participants showed an improved awareness of the threat of volcanic activity.

In 1994, participants were not prepared for earthquakes. They did not know what to do to protect themselves during an event, with some participants declaring that they would stay in bed and none answering that he or she would try to leave a building

Table 4. *Furnas: 2017 participants' awareness sources of information on extreme natural events*

There is hazard information	38%
There is no information	31%
No answer	17%
There is minimal hazard information	14%

*$n = 54$.

after a quake (Dibben and Chester 1999). Dibben and Chester (1999, p. 141) identified the reason for their behaviour as a 'fear that the ground would open up and (because of) civil defence guidelines that advised people to stay indoors and shelter under door frames'. By 2017, participants were much more aware of the possibility of earthquakes and pointed out that their children were trained at school, and they were also informed at work, to evacuate buildings in the event of an emergency, which included earthquakes. Since 2003, several low-magnitude seismic swarms have occurred between the Fogo and Furnas volcanic areas, and in 2005 the seismic swarm reached a peak when thousands of low-magnitude events were registered (Viveiros *et al.* 2008). In September 2005, the seismic crises produced two felt earthquakes with magnitudes of 3.9 and 4.3, and with epicentres located in the central part of the island (Marques *et al.* 2005). Despite the moderate magnitude of these earthquakes, they did not cause severe damage or any casualties (Marques *et al.* 2005). Similarly, the seismic swarm in 2008 did not cause damage in Furnas but may have contributed – in combination with the educational programmes mentioned above –to a rising level of awareness among the inhabitants. In summary, the 2017 participants were more risk aware than those of 1994.

The results show a developing awareness of the monitoring being carried out by scientists but the availability of information leads neither to significant improvements in its dissemination nor to changing attitudes. Nathe (2000), drawing on 30 years of experience in public education about earthquakes in the USA, suggests some important guidelines. One of these is the need to be clear about messages sent out to the public by various media channels. Public educators have to speak to each other and send one clear message to explain risks and what is required to reduce the potential for damage. Most participants in 1994 stated that either they did not know what they would do in the case of emergency or stated that they would run away without knowing where and how to leave the village in such circumstances. Figure 4 summarizes the 2017 results and shows that 68% of participants would 'run away' or not know what they should do, whereas in 1994 there were higher levels of ignorance. Neither in 1994 nor in 2017 did participants have a clear idea of what was required of them.

One feature of changing attitudes is that none of the 1994 participants mentioned following instructions from the civil protection authorities (Dibben 1999; Dibben and Chester 1999), whereas in 2017 this was raised by 21% of participants. Some 11% declared that they were aware of where to go in the event of a volcanic eruption, and these results support a conclusion that the population has become more aware of threats from extreme events over the 23 years that separate the two surveys. The reason for this change in attitude may be linked to the work that the authorities have undertaken since the early 2000s. Following the creation of the Regional Service for Civil Protection and Fire-Fighting (SRPCBA), this authority has coordinated and supervised civil protection, and has also provided training programmes in schools and at public events where people have been taught how to prepare for and act during earthquakes (http://www.prociv.azores.gov.pt). In addition, following legislation in 2006, the civil protection authorities have been responsible for issuing warnings, alerts, and organizing intervention, support and rescue. Consequently, the civil protection authorities are mentioned on

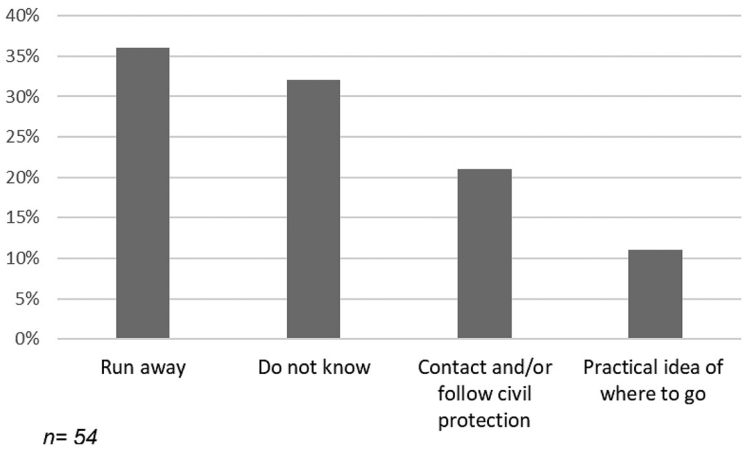

Fig. 4. Suggested reactions to a volcanic emergency as revealed in the 2017 survey.

the television news and in the print media every time there is a warning, and such actions over a long period of time can only serve to increase the population's awareness. Similarly, school sessions carried out by scientists from IVAR/CVARG have introduced children to geophysical, geochemical and geodetic monitoring research in volcanology, and may have also contributed to increased awareness.

With respect to the group of participants who stated that they were aware of a specific place to which they wished to evacuate in the event of an emergency, only one participant (Participant 9) chose a safe place: Nordeste. Participants 6 and 38 responded 'out of the island'; Participant 11 and Participant 27 indicated that they would head to the sea but provided no further explanation. Both answers demonstrate a vague idea of where to go. Participant 3 stated 'to the sea in Ribeira Quente', but this settlement (Fig. 1) would be one of the worst possible options because it lies on the lower flank of Furnas volcano and is exposed to multiple extreme events that include, for example, flooding, landslides and lahars, as well as the effects of more direct volcanic action. Overall, the 2017 participants showed a slight improvement in their awareness and behaviour with regard to both earthquake and volcanic eruptions. Many participants, though, still had similar attitudes to those interviewed in 1994: they did not have a clear idea of how and where to go should an eruption occur.

Volcanic gases: awareness and preparedness

Furnas volcano is a hazardous environment even when the volcano is not erupting. The volcano discharges levels of CO_2 that, in some parts of Furnas village, have implications for the safety of its inhabitants (Guest *et al.* 1999, 2015; Viveiros *et al.* 2015). Pedone *et al.* (2015) found that fumaroles produce the highest contribution to CO_2 (*c.* 50 t/day), followed by the springs (*c.* 9.2 t/day). The majority of CO_2 is released as silent, invisible diffuse soil emissions. Baxter *et al.* (1999) measured emissions in a ground-floor bedroom in dwellings within the village and found that these were high enough to be potentially lethal just over a 2 h period. CO_2 also carries radon gas in concentrations that are directly correlated to the levels of CO_2 (Baxter *et al.* 1999). The gas ^{222}Rn is a potential indoor threat to the health of the inhabitants of Furnas, being recognized as a causal factor in lung cancer, 'but considerable uncertainty exists over the estimates of the cancer risk from indoor' exposure (Baxter *et al.* 1999, p. 103 and reference therein).

In terms of gas emissions, the precautions taken include the ventilation of the lower floors of buildings (Silva *et al.* 2015; Viveiros *et al.* 2015). Dibben's work revealed that none of the participants surveyed thought that gas emission was a hazard in Furnas. In fact, a high proportion of participants thought emissions to have a healing effect (48%). The second most common answer was fatalistic and stated that people were used to living with perils (Dibben 1999, p. 220). One person answered that degassing represented a pressure release for the volcano. In 2017, only one participant associated the gas with pressure release from the volcano, whilst all the others answered that they knew about the gases and they also knew how to cope with these risks. Participant 9 gave a typical answer: 'everyone knows about gases. If they open a hole, gases come out. But if a man knows how to act, he won't be harmed'.

Dibben's participants did not know that they needed to protect themselves against CO_2 discharge and did not take the precaution of ventilating their homes. By 2017, the exposure to indoor gases was diminished because new buildings had basements that did not make direct contact with the soil because they were constructed over ventilated void spaces (Silva *et al.* 2015). This change in building practice demonstrates an improvement in both the awareness of hazardous gases and of ways by which people might protect themselves (Silva *et al.* 2015; Viveiros *et al.* 2015). This increased level of awareness is probably related to the work carried out since the 1990s by the University of Azores, which has deployed fixed stations to measure gases and visits to the area by scientific personnel have become commonplace. Scientific personnel have also been involved in studies using portable stations located both within houses and outdoors (Silva *et al.* 2015). This was recalled by Participant 13, who not only remembered research on gases but also the spread of information. Despite these improvements, some of the 2017 participants were less aware of the threat posed by gases. For example, Participant 8 explained, 'I know about the gases even inside houses. My cousin has fumaroles inside the house, he cooks on it (sic)'. This participant also agreed to guide the researchers around his/her garden and show them the fumaroles. Participant 8 explained how the family originally tried to use the fumaroles for heating but gave up after a short time because the pipes became corroded, indicating how people try to take advantage of, and cope with, their environment. When the family of this participant realized it was not possible to remain in their home, they moved 20 m away and used the original building as a garden store. It is because they were aware of degassing, but were unaware of scientific details over unsafe discharges, that they place themselves in potentially dangerous situations. On the other hand, Participant 13 was well aware and described how his family coped with the gases released by observing the behaviour of insects (beetles), 'If they looked dizzy, they knew that it was

necessary to ventilate the apartment and leave for a while'.

Risk perception

Ricci *et al.* (2013, p. 123) refers to risk perception as:

> [A] general term that encompasses a number of different aspects of how people may view their risk from a particular hazard. These include the perceived likelihood of a disaster, perceptions of how serious such an event might be, how personally one might be affected, and how worried one is about a potential threat
>
> (Ricci *et al.* 2013, p. 123).

Risk perception is also influenced by social and economic factors, and varies in accordance with each individual's personal experience of the hazard, knowledge, preparedness and confidence in decision-makers (Pidgeon 1998; Paton *et al.* 2010).

Examining beliefs and the construction of risk, Dibben reports how in the 1990s the inhabitants of Furnas did not view volcanic threats as a major issue of concern and, during the May–June 2017 survey, this was still the opinion of the majority of the participants. Dibben and Chester (1999, p. 140) stated that all participants were well aware of both living on a volcano and within a caldera. In 2017, all participants except one declared they were aware of living inside a volcano.

Land attachment

Attachment to the land and a sense of belonging to a community influence how people may react in an emergency (Paton 2003). In 1994, the participants showed elements of land attachment (Dibben and Chester 1999), as did the 2017 participants. In 2017, 70% stated that they had never thought of living anywhere other than Furnas, while one had lived abroad and moved back (Participant 8). Some 19% answered 'I do not want to leave because I love this land'. Among the participants who thought about leaving (22%), 33% said 'for work' and 17% for 'family issues'. The other half would leave because 'I have not adapted to the Furnas environment; yes, I have thought about it many times (but) it is not easy to adapt here' (Participant 10). Some participants who responded that they were born in Furnas, also stated that their families had lived in the village for more than 100 years. Among those who felt a strong attachment to the land, there was one participant who provided further details mentioning the attachment he or she had to the village and how much they desired to transmit this feeling to their sons. These results reflect the descriptions from elsewhere (Bonaiuto *et al.* 2016) of the long-term bonding of people to their homes and communities (Dibben and Chester 1999, p. 143).

Livelihood, resources, self-protection and resilience

In the event of a future earthquake or volcanic eruption causing material damage, 94% of participants stated that the government, through social welfare payments, would act to repair the damage. Further help would come from family and friends (65%), and from personal savings (49%). These results reflect the fact that 57% of participants in 2017 do not have insurance to protect either their health costs or the funds needed to rebuild or repair their homes. In 1994, the participants without insurance were 78% (Dibben 1999). During the 2017 Furnas interviews, three participants (Participant 12, Participant 14 and Participant 29) stated that insurance did not cover volcanic perils, and this was confirmed by insurance companies writing policies on the island. Insurance rates across São Miguel are the same regardless of location or postcode but policies take into account the type of construction, in particular its age (i.e. built before or after 1985, roofing characteristics and overall condition: e.g. Fidelidade Insurance 2018). Usually policies cover fire, electrical risks, storms, landslides, floods and seismic risks.

Discussion

This research is an example of a longitudinal study that covers more than 20 years, and which compares hazard and risk awareness of participants in 2017 with those surveyed in 1994 (Dibben 1999). An increase in participant's hazard and risk awareness may be a result, therefore, of hazard education and/or experience of natural perils (e.g. Paton *et al.* 2000). In Furnas, no volcanic eruptions have occurred since 1630 (Gaspar *et al.* 2015), and between 1994 and 2017 the Furnas area was affected by seismic swarms (2005 and 2008) that did not cause major disruptions in the village (Marques *et al.* 2005; Viveiros *et al.* 2016). However, from May to September 2005 the seismic activity produced thousands of instrumentally detected earthquakes and over 100 felt quakes (Gaspar *et al.* 2015; Silva *et al.* 2015; Wallenstein *et al.* 2015). CO_2 cold springs, thermal springs and emissions of steam are present within the village and its surrounding area (Viveiros *et al.* 2015). Since the late 1990s, the Azores Civil Protection and Fire-Fighting Service (SRPCBA) has organized educational programmes targeting people of different ages. These programmes concern seismic risk; however, similar initiatives to heighten volcanic preparedness do not exist (Rego *et al.* 2018). In addition, the Centre for Information and Seismovolcanic Surveillance of the Azores (CIVISA) and the Institute for Research in Volcanology and Risk Assessment (IVAR) have

run courses on hazards for hundreds of schoolchildren (Wallenstein *et al.* 2015). It is because seismic events have not caused major injury of loss of life for many years that a strong case may be made for programmes of education to be put in place. McEntire and Myers (2004, p. 150) report that Nathe (2000) remarked:

> [H]azards education attempts to increase protective actions by people, groups and institutions by presenting information about a hazard and the risk it poses in order to create uncertainty in people's minds'.

In 1994, before any targeted hazard education and despite the lack of awareness of the possibility of extreme volcanic events, participants had some awareness of risks related to earthquakes but they were unaware on how to protect themselves. Awareness has developed over the past 20 years, as is revealed in participants' perspectives as recorded in the 2017 survey. Increasing awareness may also reflect change at the political level in the support that the regional government has provided for the work of SRPCBA, CIVISA and IVAR in disseminating appropriate information and in trial earthquake evacuations in schools or working places, although the extent to which individual residents of Furnas took part in these initiatives is unknown. The Furnas results agree with the findings of Nathe (2000), who stressed that when dealing with hazard education, the best results may be achieved when: educators support their audiences in raising appropriate questions; the authorities offer simple and clear instructions; and the population is supported by the authorities in order to reduce uncertainties. Despite these improvements, the vast majority of the participants in 2017 did not know what to do in the event of a volcanic eruption and would have to rely on bodies such as the civil protection authorities and the regional government to make decisions on their behalf. Some participants showed confidence that the civil protection authorities will guide them in the case of a future emergency. Rego *et al.*'s (2018) findings on perceptions of seismic and volcanic risk and preparedness in São Miguel Island showed a similar confidence in the SRPCBA actions. As Paton (2007, p. 371) notes, 'when dealing with natural hazard issues, people rely on sources with whom they have a general relationship that extends beyond natural hazard issues'. In Furnas, the dialogue opened between the civil protection authorities, the university and the wider population seems to have cultivated a level of confidence which is illustrated by Participant 13's statement that 'University of Azores is the best and contributes to the quality of our life'.

Yet, an overall comparison between participants in 1994 and 2017 showed only limited improvements in hazard awareness and this supports the idea that building awareness takes a long time, especially because changing attitudes is a slow process. The results of this paper reflect the findings of Bird *et al.* (2020) on volcanic hazard and risk awareness of tourists in south Iceland. Their longitudinal study focused on a range of stakeholders in order to evaluate initiatives and events to raise awareness of volcanic hazard and risk in relation to evacuation exercises, educational materials and experience from 2004 and 2017. The results showed that over many years these initiatives had only influenced a limited number of people, whilst the majority remained unaffected (Bird *et al.* 2020). There are examples of initiatives that have raised awareness over shorter time intervals (Mileti and Brien 1992; Mileti and Fitzpatrick 1992; Mileti and Darlington 1997; Shenhar *et al.* 2015, 2016). Shenhar *et al.* (2015, 2016), for example, evaluated the perceptions of approximately 1000 participants who were exposed to earthquake hazard awareness campaigns on the media that ran three times between 2011 and 2013. Shenhar *et al.* (2016) found that in 2013 there had been a significant improvement in levels of knowledge of what to do in the event of an earthquake. In future, it may be valuable to run not only educational courses but also television, radio and other media campaigns targeting different age cohorts in order to raise population awareness without causing unnecessary fears, as has been the case with certain examples of health promotion (Wakefield *et al.* 2010). The development of appropriate role-playing games would contribute in enhancing awareness. Role-playing games have been shown to be reliable in increasing warning communication literacy and enhancing collaborative capacity in disaster-prone areas (Gampell and Gaillard 2016; Solinska-Novak *et al.* 2018; Weyrich *et al.* 2021).These initiatives, targeted to the intended audience's needs, beliefs and expectations, would have to be undertaken over a long time because, as Nathe (2000) points out, all training of this type has to be carried out on numerous occasions in order to make it effective in raising awareness.

Conclusion

This longitudinal study provides a contribution to understanding the evolution of hazard awareness in Furnas. Participants in 1994 and 2017 were in agreement that volcanic threats are not a major area of concern because they did not think an eruption would occur during their lifetimes, this perception being based on the observation that they did not see any evidence of change in the volcanic or seismic characteristics of the area. In 2017, participants were more conscious than in 1994 of threats posed by gases, and many participants were aware of self-protection measures. With respect to earthquakes, people were

more knowledgeable about appropriate responses in the event of an emergency. They also knew reliable sources for earthquake and volcanic information.

Some participants showed confidence that the civil protection authorities would guide them in the event of an emergency. Rego *et al.*'s (2018) research on perceptions of seismic and volcanic risk and preparedness across São Miguel found a similar level of confidence in the efficacy of SRPCBA actions within their participant groups. Direct reference to trust in the authorities was not mentioned by participants in our study, although this was not specifically asked. Indeed, understanding how the confidence in the abilities of the civil protection authorities may translate into trust is something that could be investigated in future research.

In 2017, knowledge of where safe destinations were to be found in the case of a volcanic emergency were still lacking and respondents were prepared to leave the details of evacuation to the civil protection authorities. If evacuation is not carefully planned and carried out, individuals may choose either not evacuate or evacuate in an unplanned way without informing (Bird *et al.* 2010). According to Johnston *et al.* (2005), the combination of a lack of knowledge and high levels of uncertainty can lead to an unsafe behavioural response where many individuals fail to respond to an evacuation request in an appropriate manner. In contrast, Brilly and Polic (2005) suggest that an individual's initial response may be to evacuate before seeking appropriate information. Furnas is surrounded by steep slopes formed from poorly consolidated materials and massive lava-flow horizons. This geology is conducive to the generation of landslides and rockfalls, resulting from seismicity (Dibben and Chester 1999). It is not possible, therefore, to provide the inhabitants with one evacuation plan for every possible scenario. Instead, Furnas inhabitants should be involved not only in training sessions but also in the evacuation planning process so they might develop an awareness that scenarios of evacuation may change following the event. The community has not been involved to any significant extent up until now and there is no formal two-way dialogue. A dialogue would further promote collaboration between the authority and the population. Moreover, in the case of emergency, the inhabitants of Furnas may respond to an evacuation call in an appropriate way.

In summary, policy initiatives taken by the authorities over the past two decades are still a 'work in progress', although advances have been made in increasing awareness of the threats posed by volcanic gases and earthquake hazards, and in the dissemination of knowledge of self-protection.

Nevertheless, increasing awareness of possible future eruptions is a very difficult policy goal, especially on a volcano that has not erupted since 1630 but which, when it does, will have a severe impact on the inhabitants of Furnas, and this justifies the authority's long-term commitment to community education.

Acknowledgements

Author contributions **AL**: conceptualization (lead), data curation (lead), formal analysis (lead), investigation (lead), methodology (equal), writing – original draft (lead), writing – review & editing (equal); **JS**: conceptualization (equal), formal analysis (equal), methodology (equal), supervision (equal), writing – review & editing (equal); **VK**: conceptualization (equal), supervision (equal), writing – review & editing (equal); **NW**: investigation (supporting), resources (supporting); **RC**: investigation (supporting), resources (supporting); **DC**: conceptualization (equal), resources (supporting), supervision (equal), writing – review & editing (lead); **AD**: conceptualization (equal), methodology (supporting), resources (supporting), supervision (equal), writing – review & editing (equal); **CD**: methodology (supporting), resources (supporting), writing – review & editing (supporting); **FF**: investigation (supporting).

Funding This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability The datasets generated during and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS].

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