Natural Hazards
https://doi.org/10.1007/s11069-024-06845-1

ORIGINAL PAPER

Tsunami risk perception of the touristic population of Stromboli Island: towards effective risk communication strategies

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Received: 11 January 2024 / Accepted: 22 July 2024

Abstract
This study focuses on the risks that tourists would face during a tsunami on the island of Stromboli and discusses how to best inform and prepare them. Tsunamis affect coastal regions, where many of these are leisure destinations for tourists who often don't have adequate knowledge of the region's risks. Due to their proximity to the affected areas, near-source or local tsunamis usually allow for a limited warning time, posing great challenges to the planning of effective risk mitigation action. Furthermore, tourist populations have a particular significance in studies on risk perception, since their needs intersect with those of the local population and must be taken into account. To gather key knowledge for developing robust risk communication strategies, a survey (n = 699) was conducted between July and October 2023 to assess tourists' risk perception and preparedness. The findings indicate that tourists often misdescribe tsunamis, leading to underestimation of the security threats posed by smaller events and revealing shortcomings in current communication approaches. Given the tourism industry practices on the island, effective communication strategies for tourists should prioritize providing comprehensive information within the first 24 h of their arrival. Furthermore, given the high percentage of tourists who visit the island for a few hours and within certain time slots, we invite the authorities to provide this information before disembarking on the island.

Keywords Tsunami · Stromboli · Mass tourism · Risk perception · Risk communication · Risk mitigation

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Published online: 31 July 2024

1 Introduction

Seismic-triggered tsunamis gained attention after the 2004 IOT, which caused more than 230,000 casualties across the Indian Ocean and some USD 14 billion in damage, displacing 1.6 million people (Rofi et al. 2006; NCEI/WDS 2023). Recently, volcano-induced tsunamis have received increased global attention (Nomikou et al. 2014; Mutaqin et al. 2019), especially after the 2018 Anak Krakatoa (Indonesia) and the 2022 Hunga Tonga tsunamis (e.g., Heidarzadeh et al. 2020; Pakoksung et al. 2022).

The IOC-UNESCO developed early warning systems to monitor tsunamis regionally, aiming to enhance response capacity, minimize human casualties, and safeguard affected communities livelihoods (e.g., Lauternjung et al. 2010). In 2005, three Intergovernmental Coordination Groups to oversee tsunami monitoring and alerting in the Northeast Atlantic, the Mediterranean, and Connected Seas; the Indian Ocean; and the Caribbean and Adjacent Regions, respectively were established.

To coordinate tsunami alerts. Italy established the National Warning System for Tsunamis (SiAM) in collaboration with CAT-INGV, ISPRA, and the DPC Historical data reveals Italy's susceptibility to tsunamis, with 70 documented events affecting its coasts since AD 79, according to the Euro-Mediterranean Tsunami Catalog (EMTC 2.0). 27 of these occurred between Sicily and Tyrrhenian Calabria and 16 occurred in the Tyrrhenian Calabria and Aeolian Islands region, as documented by Tinti et al. (2003) and Maramai et al. (2005b, 2019). Locally, we must mention the volcanic-induced tsunami that occurred on the island of Stromboli following the volcanic activity that started on December 28, 2002. On December 30 a tsunami hit the coasts of the island, also reaching the other Aeolian islands and the coasts of Calabria and Sicily (Tinti et al. 2005). The magnitude and characteristics of this event highlighted the hazardous nature of the island and outlined the destructive potential of cascading events. This marked a threshold in the scientific community and civil protection institutions, which led to a change of direction in the monitoring methodologies of Stromboli Island and to the creation of a tsunami warning system implemented ad hoc for the specific situation (Bonilauri et al. 2021; Selva et al. 2021).

The present paper is part of an ongoing research born from the 2022–2025 Arrangement between DPC and INGV. The research aims to gain insight into the tsunami awareness of the island's inhabitants. While, due to its nature of volcanic island, Stromboli is exposed to multiple hazards our study chose to specifically focus on tsunamis for several reasons. Firstly, tsunami sources for Stromboli Island may be different and not necessarily associated with momentary eruptive activity. In fact, several past tsunamis were triggered by landslides that weren't preceded by natural precursors or warnings. The geomorphologic characteristics of the Island make tsunamis a distinct and significant threat to coastal communities on the Island, the Aeolian archipelago, and the Italian coasts near the volcano. Therefore, locals, tourists, and anyone visiting the Island must be aware of the natural signs and warning systems on the Island in order to react properly in case of an emergency. Secondly, while volcanic eruptions are a well-documented hazard on Stromboli, the likelihood and potential impact of tsunamis in the region may be less well understood or addressed. The island's inhabitants are distinguished as tourists and local residents, and different data collection methodologies are designed to meet the needs of these different populations and the different cognitive requirements of the research. A multilingual survey was promoted among tourists to collect quantitative data on their knowledge of the phenomena and their level of awareness regarding the alert system and emergency protocols. These data will be the focus of the paper. Semi-structured interviews and more qualitative focus groups have

been planned for residents, but have not yet been conducted at the time of writing. The results of the research will support INGV and DPC, together with the regional government and the municipality of Lipari, in conceiving the contents and methods of tsunami risk communication on the island.

2 Research context

2.1 A multi-hazard island

Stromboli is a volcanic island part of the Aeolian Archipelago, located north of Sicily and west of Calabria along the Southeastern Tyrrhenian Continental Slope. Its volcanic edifice spans from 1700 to 2000 m under the sea level to 924 m above, and it's prone to frequent collapses (Giordano and De Astis 2021). Like most volcanic islands, its position, the volcanic activity, and the presence of human settlements and economic endeavors characterize it as a multi-hazard environment.

The constant strombolian activity of the volcano, with its mild explosions every 10–20 min and ejection of material at 100 m of height, is offered as a naturalistic marvel for tourists to experience in their leisure. These strombolian phases alternate with periods of heightened activity, featuring major explosions that propel volcanic bombs and other materials to heights of hundreds of meters. Paroxysmal explosions can result in volcanic columns ascending several kilometers into the sky. Effusive activity also occurs, during which lava is generated and expelled from new lava vents or eruptive fissure openings on the Sciara del Fuoco (SDF), situated on the northwest side of the volcano (Giudicepietro et al. 2022).

Most of this volcanic activity can generate mass flows (i.e., hot avalanches, collapse of the pyroclastic column, subaerial and submarine collapse of the volcanic edifice) that can displace large water volumes. Eight tsunamigenic events resulting from mass movements have been recorded as directly caused by Stromboli volcanic activity (Maramai et al. 2005b, Esposti Ongaro et al. 2021).

The last notable event of this nature is the tsunami generated in Stromboli in December 2002. Thermal and optical monitoring of the volcano indicated that effusive activity started on December 28th with lava flowing into the sea from a volcanic fissure at 750 m on the SDF (Calvari et al. 2005). On the 30th of December, the additional weight of the lava flow and the steep slope on the SDF led eventually to several collapses including a subaerial collapse with no tsunamigenic consequences, followed by a submarine collapse in a range between 16×10^6 m^3 and 19×10^6 m^3 that generated a tsunami (Pino et al. 2004; Tinti et al. 2005). The tsunami was estimated to hit the island's entire coast in less than 4 min (Tinti et al. 2006), with a local run-up height of 10 m and inundation effects locally visible at 150 m inland (Tinti et al. 2005).

The impact severely damaged buildings on Stromboli, while the effects on the nearby Aeolian Islands and the broader area were gathered through eyewitness accounts following the Intergovernmental Oceanographic Commission's guidelines (IOC). These observations formed a database for simulations, hazard analyses, and damage scenarios (Maramai et al. 2005a).

Computer simulations model larger flank collapses, aiding in preparing for worst-case scenarios (Tinti and Bortolucci 2001; Esposti Ongaro et al. 2021) and understanding past catastrophic events, like the formation of Sciara del Fuoco. Simulated landslides of nearly

1×109 m^3 could trigger tsunamis reaching remote island areas in under four minutes, with a 50-m run-up height (Tinti et al. 2000) and waves of 5–10 m impacting Calabria's Tyrrhenian coast (Tinti and Bortolucci 2001).

2.2 Studies on tsunami risk perception

As stated in Wachinger and Renn (2010) contribution to the understanding of risk perception comes from all social sciences, each describing the psychological, social, and cultural factors that shape held beliefs and how available information is perceived and processed. From a psychological perspective, the main stream of research on risk perception includes research on collective and individual heuristics, which helps understand the strategies used to simplify responses to complex realities (Elster 1983; Slovic 1986; Siegrist and Arvai, 2020). The psychometric paradigm approach describes how on a cognitive and affective level different qualitative risk characteristics are attached to different hazards (Kahneman and Tversky 1979; Slovic et al. 1984; Slovic 1987). From a sociological perspective, research focuses on how social groups and political institutions influence individual judgment (Wachinger and Renn 2010) and how others' behaviors and beliefs impact one's own through social interaction (Hedstrom and Swedberg 1998; Hedstrom 2005). This involves how information is mediated and accepted (or discarded) based on one's value-laden frame of reference, often reaffirming existing attitudes (Dunwoody and Peters 1992; Breakwell 2007). Furthermore, the cultural theory approach describes how cultural, religious, and ideological constraints on beliefs shape perceptions and behaviors (Douglas and Wildavsky 1983; Douglas 2007). Finally, the social amplification of risk theory then uses communications theory to describe how signals generated from risk events are amplified or attenuated passing from one receiver to another, affecting the perception of risk and related behaviors (Kasperson et al. 1988).

From this wider body of research streams of international literature followed, focusing their effort on the risk perception of specific natural hazards (e.g., for seismic risk perception see Armas 2006; Crescimbene et al. 2014; Santos-Reyes et al. 2017, Hua et al. 2020; for volcanic risk perception see Carlino et al 2008; Paton et al 2008; Ricci et al 2013; for landslides risk perception see Finlay and Fell. 1997; Gravina et al. 2017;Alam 2020). Among these, studies on tsunami risk perception have met with growing interest following the 2004 Sumatra event. Since then, the perception of tsunami risk among the populations in the Indian and Pacific Oceans has been examined, both post emergencies (Kurita et al. 2007; Couling 2014) and in peace-time (Bird and Domeney-Howes, 2008; Mengal et al. 2020; Salah and Sasaki 2021). A recent focus on the NEAM Region began under the EU Assessment, Strategy, and Risk Reduction for Tsunamis in Europe (ASTARTE), leading to research in Norway (Goeldner-Gianella et al. 2017), Portugal (Liotard et al. 2017), and Romania (Constantin et al. 2017). Outside of ASTARTE, surveys examining tsunami risk perception were conducted in Italy, particularly in the Southern and Central Regions (Garavina et al. 2019; Cerase et al. 2019; Cugliari et al. 2022). From this growing body of literature, it is possible to draw indications on how individual variations in tsunami risk perception relate to socioeconomic status, age, gender, proximity to hazards, knowledge, and historical memory of past events (Akbar et al. 2020; Dhellemmes et al. 2021; Arias et al. 2017; Cerase et al. 2019; Cugliari et al. 2022).

Of particular interest are the few studies that include transient populations such as tourists in their research design (Arce et al. 2017; Hall et al. 2019). The tourism industry thrives in regions of environmental and naturalistic interest, which adds to the resident

population's needs in terms of risk management and risk communication. Tourists are generally less aware than residents of the risks, the behaviors to adopt, and the protocols to follow (Goelder-Gianella et al. 2017). Filling this knowledge gap becomes essential for the effectiveness of risk mitigation strategies.

2.3 Communication strategies for volcano-related tsunamis in Stromboli

Designing effective communication strategies to reach different segments of the population in a given context, and providing crucial information to adopt life-saving behavior in the event of an emergency, is an ongoing challenge in the field of communication. This is particularly relevant for places such as Stromboli, where tsunamis can result from difficult-to-monitor events such as the collapse of a volcano's flank. In such situations, it is crucial to strengthen communication strategies to engage both the individual and the community in a continuous and inclusive plan (Barclay et al. 2008; Sakurai & Adu-Gyamfi 2020).

In recent years, after tsunami-inducing volcanic events, such as the eruption of Anak Krakatau on 30 June 2018 and the tsunami caused by the eruption of Hunga Tonga Hunga Ha'apai on 14 January 2022, there has been an increased focus on multi-scale communication aspects across different intergovernmental agencies (Walter et al. 2019; Ray-Bennett et al. 2020; Lynett et al. 2022).

Regarding risk communication on Stromboli Island, research centers and the Italian Civil Protection Department supervise the implementation of an early warning system based on a multidisciplinary network that scans the volcano and the surrounding sea monitoring for precursors of heightened volcanic activity (Calvari et al. 2022) and for the onset of tsunamis (Bonilauri et al. 2021). An island-wide acoustic system with distinct signals alerts of imminent tsunamis or paroxysmal explosions. Signage scattered on the island indicates evacuation routes leading to designated waiting areas (see Fig. 1).

Along with the monitoring activities, over the last years the Italian Civil Protection Department in collaboration with research institutions and volunteer organizations promoted the IoNonRischio[1] campaign to raise awareness within the resident population of the volcanic and tsunami hazards of the island, in an attempt to convey scientifically correct information and foster the adoption of risk reduction behaviors.

This type of dissemination activity aimed at the resident population tends to neglect the awareness of the many visitors that arrive in Stromboli each year, and no active effort is planned to reach what in the tourist season becomes the most important demographic on the island in terms of size. Since the '50 s the Aeolian volcanoes piqued tourist interest among private and university groups (Knafou 2019). Stromboli's residents converted buildings into accommodations, expanded constructions in tsunami-prone areas (Bonilauri et al. 2021), and geared local production toward hospitality (Pitto 1990). Tourism became the principal revenue source for the Aeolian Islands, reaching 487.907 presences in 2019 (Marasco et al. 2022). As tourism industry developments encourage more arrivals in destinations of naturalistic interest, its sustainability in areas vulnerable to catastrophic events remains a concern, and efforts are required to secure its long-term viability (Orchiston 2011). Observations during the August 2019 paroxysmal explosion highlighted the need

[1] https://www.iononrischioprotezionecivile.it/en/.
https://iononrischio.protezionecivile.it/en/get-ready/volcanoes/stromboli/.

Fig.1 Signs for the evacuation routes. **A** Tsunami hazard signal with evacuation instructions, Ficogrande beach, Stromboli Village; **B** Waiting Area sign, Piscità, Stromboli Village; **B** Escape Route sign, Via Roma from the harbor, Stromboli Village. Photos provided by one of the co-authors

for targeted risk communication campaigns to enhance tourists' responsiveness (Bonilauri et al. 2021).

From a social science standpoint, the effectiveness of even the most technically advanced early warning system or civil protection plan hinges on community acceptance. As Becker et al. (2020) underlined in the context of earthquake risk awareness, acceptance is facilitated not only by the knowledge of the hazards but primarily by the involvement in strategic planning of the affected communities to produce more people-centered early warning systems. Participation is the key to bridging the ''last mile'', ensuring clear understanding and acceptance of alert signals and instructions (Loster 2012; Macherera and Chimbari 2016). For Stromboli, this involves residents, property or industry owners and workers, and the annual influx of tourists. Ensuring tourist safety in adverse circumstances is the only effective way to maintain over time an industry heavily exposed to exogenous shocks (Hall et al. 2023).

3 Research goals

Perception of potential harm from events influences decision-making and behavior. Legislators and risk communicators must account for risk perception when developing emergency communications and evacuation protocols (Lorito et al. 2021; Valbonesi 2021; Vinnell et al. 2022; Clouard et al. 2024).

Current literature on Italian tsunami risk perception (see Par.2.1) focuses on coastal residents perceptions (Cerase et al. 2019; Cugliari et al. 2022), neglecting tourist populations

in hazard-prone areas like Stromboli. This study aims to fill this gap by examining tourist risk awareness and perception regarding potential Stromboli tsunamis through the following research questions:

RQ1: What is tourists' tsunami risk perception in Stromboli?

RQ2: How do individual factors like age, gender, education, and media habits influence tourist tsunami risk perception?

RQ3: How do factors like length of stay, and travel party affect exposure to tsunami risk information and hazard understanding?

RQ4: Which features aid awareness of the procedures and disaster preparedness among tourists?

Answering these basic questions can reveal gaps in tourists knowledge that risk communication must address, and provide insight for context-tailored communication efforts.

A second phase in May–September 2024 will investigate resident risk perception through semi-structured interviews and focus groups.

4 Methodology

4.1 Data collection

The 40-item research questionnaire is based on the one used by Cerase (2019) and Cugiliari et al. (2022) for the study on tsunami risk perception in Italy. From the above-mentioned questionnaire, the items on the expected effects of a tsunami, information sources on tsunami risk by respondents, tsunami knowledge (phenomenon), and the causes that can generate a tsunami were respectively borrowed. The background section was modified to suit the Stromboli context and target audience, and scaling adjustments on the probability perception items were also made to ensure comparability between assessments at different geographical scales. Finally, a section was added with items pertaining to familiarity with evacuation routes, preferred emergency communication methods, the roles of local and national authorities, and intended behaviors during emergencies. Additionally, three questions about the acoustic signals used in Stromboli's alert system were added to this last section during the survey.

To encourage broad participation, the questionnaire was translated into English, French, Spanish, and German, but this limited access for tourists who didn't speak any of these languages. Responses were gathered using Computer-Assisted Web Interviewing (CAWI), offering respondents flexibility in completing the survey. Some Computer-Assisted Personal Interviews (CAPI) were conducted based on participant availability. QR codes leading to the survey were strategically placed across the island near notable spots and tsunami warning signs. Collaborating with local tourism bodies aided in distributing QR codes, ensuring effective reach among tourists. Over 84 days from July to October 2023, the survey gathered 699 responses. While this collection period provided substantial data, potential limitations stemming from sampling biases inherent in the methodology must be recognized.

The CAWI method relies on self-selection, potentially causing selection bias and underrepresentation of elderly or lower-educated tourists, thus affecting the sample's age and educational diversity compared to the actual tourist population (Wright 2019). To counter this, research personnel were present on the island to assist tourists with the CAPI method. Additionally, close collaboration with local tourist services aimed to mitigate estimates'

distortion. The true demographic makeup of the surveyed tourist population remains unknown; therefore, it is not possible to produce a proportional sample and the distance from it cannot be calculated. Nevertheless, the large presence of high educational qualifications may highlight even more the need for further awareness-raising actions aimed at all tourists.

4.2 Measures

The risk is a complex construct modeled on the combination of three indicators: hazard, exposure, and vulnerability, to which the Sendai Framework for Disaster Risk Reduction added capacity, intended as the ability of individuals and organizations to successfully manage the risks to which are exposed (UNISDR 2018). Risk can thus conceptually be expressed by the following formula:

$$Risk = \frac{\Pi(Hazard, Exposure, Vu\ln erability)}{Capacity}$$

We modeled risk perception measurements on underlying concepts to compare them with effective tsunami risk.

To create a Hazard Perception, measure like an effective hazard assessment (Basili et al. 2018), we defined hazard perception as considering both the perceived probability of a tsunami occurring and its perceived physical magnitude. Our survey included two 5-point Likert scale items assessing individual estimates of the probability of a tsunami occurring in the Mediterranean Sea and in Stromboli. Two nominal scale items gauged the expected tsunami intensity: potential height and inundation length. A third nominal scale item asked what height respondents deemed dangerous for people near the coastline (see Annex A).

Capacity primarily refers to individual coping abilities, effectively mitigating the risk to which one is exposed. This capability links to awareness levels, organizational resources provided by risk management institutions, and information provision on risk-related behaviors.

Items in the survey aimed to assess individual preparedness: to gauge respondents' perception of self-efficacy a survey item asked if they knew how to act during a tsunami; subsequently respondents were asked about their knowledge of evacuation routes (refer to Annex A). These are used to design a typology that classifies respondents into four groups according to their preparedness and knowledge of risk-related behaviors. Independent sample proportions comparisons are used to describe similarities and differences between the four groups to ascertain which variables influence preparedness.

4.3 Sample description

The 699 respondents have an average age of 39.2 (SD = 13.7) years; respondents' age was divided into 5 classes as shown in Table 1.

The majority of the sample stayed on the island only one day (59.1%) and 17.2% came on the island accompanied by others who may need special care and attention, or for whom they bear responsibility (children of less than 6 years, elderly, people with reduced mobility).

Table 1 Distributions of the basic characteristics of the sample (n = 699)

Characteristics	n	%
Age		
18–25 yrs	110	15.8
26–35 yrs	212	30.4
36–45 yrs	138	19.8
46–55 yrs	128	18.3
> 55 yrs	110	15.8
Missing	1	
Nationality		
Foreign	197	28.2
Italian	502	71.8
Travelling with others in condition of fragility		
No	579	82.8
Yes	120	17.2
Gender		
Woman	372	53.2
Man	317	45.4
Prefer not to disclose	10	1.4
Education Level		
At lower secondary	27	3.9
Upper Secondary	174	24.9
Tertiary	323	46.2
Post Tertiary	175	25
Time on the island		
A day	413	59.1
More than a day	173	24.7
A week	81	11.6
More than a week	32	4.6

Italian tourists represent 71.8% of the sample, with the remaining 28.2% coming from 28 different countries.[2]

A few differences between Italian and foreign tourists can be drawn from the data. Foreign tourists tend to stay on the island for a day or a 5 days (93.9%) while Italians usually stay for a day (65.3%) but are also more likely than foreigners to stay a week or more (20.1% vs. 6.1%). They also differ for individual characteristics: foreign tourists are older on average (41.7 years vs. 38.7 years) and are more likely to have higher educational attainment (83.2% have at least a bachelor's degree v 66.5% for Italians) (see Annex B).

[2] France (8.6%), Germany (7.2%), England (1.9%), Spain (1.7%), Netherlands (1.4%), Switzerland (1.4%), Austria (1.0%), Belgium (0.7%), Czech Republic (0.6%), Romania (0.4%), Australia (0.3%), Canada (0.3%), New Zealand (0.3%), Slovenia (0.3%), United States of America (0.3%), Armenia (0.1%), Denmark (0.1%), Dominican Republic (0.1%), Finland (0.1%), Hungary (0.1%), Ireland (0.1%), Japan (0.1%), Lithuania (0.1%), Mexico (0.1%), Portugal (0.1), Serbia (0.1%), Syria (0.1%), Sweden (0.1%).

5 Results and discussion

5.1 Perception of probability

In assessing the perceived likelihood of a Mediterranean tsunami, a 5-point Likert scale was used (mean = 3.0, s.d. = 1.0) Results from Table 2 indicate that 42.1% perceived tsunamis as ''Not at all'' or ''Not very'' probable, consistent with previous studies (Cugliari et al. 2022).

To explore sources of variation in the assessment of probability, multiple one-way ANOVAs were carried out relating the probability assessment with the features listed in chap. 2.4. Every association explored was non-significant except for age ($F = 2.5$, $p > 0.05$). The average perception of probability of a tsunami in the Mediterranean Sea seems to increase with increasing age in a fairly linear fashion (Fig. 2). While this association was not recorded in previous surveys carried in the Italian coasts (Cugliari et al. 2022) is nonetheless in line with other international studies (Arias et al. 2017; Dhellemes et al. 2021) where respondents in the older age groups demonstrated better awareness and knowledge of the hazards.

When respondents are asked about the likelihood of a tsunami hitting Stromboli's coastlines, judgments tend to converge on the realm of plausibility. (Mean = 3.8 S.D. = 0.9), with

Table 2 Frequencies of response to "In the Mediterranean Sea, the likelihood of a tsunami occurring is:"

Response	n	%
Not probable at all	13	1.9
Not very probable	281	40.2
Neither probable nor improbable	129	18.5
Fairly probable	241	34.5
Very probable	35	5
Total	699	100

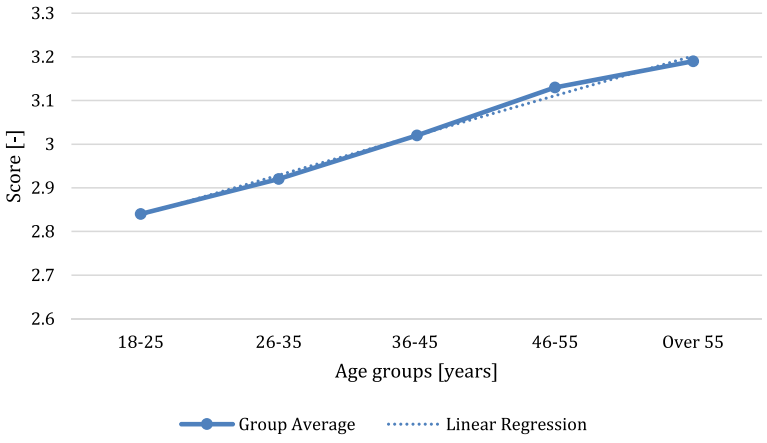

Fig. 2 Average Perception of Probability of a tsunami in the Mediterranean Sea by age groups with tendency line

Table 3 Frequencies of response to "Do you think the island of Stromboli could be hit by a tsunami?"

Response	n	%
Not at all agree	13	1.9
Slightly agree	80	11.4
Neither agree nor disagree	102	14.6
Moderately agree	348	49.8
Strongly agree	156	22.3
Total	699	100

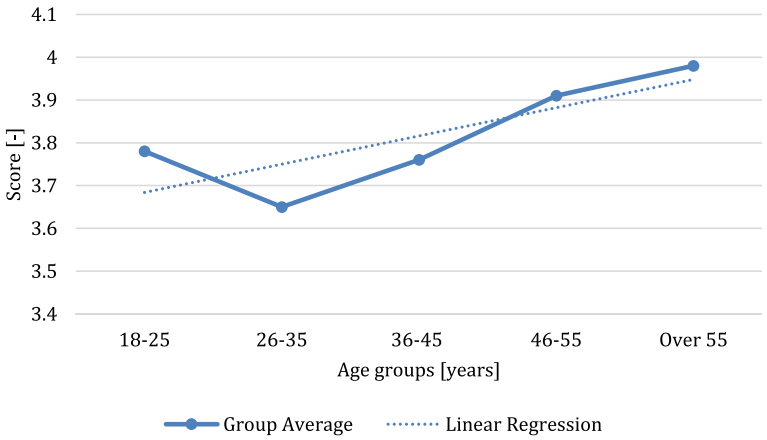

Fig. 3 Average Perception of the probability of a tsunami hitting Stromboli by age groups

72% of the sample believing that Stromboli could be hit by a tsunami, while only 13.3% disagree (see Table 3).

ANOVAs showed that the judgments on the probability of a tsunami hitting Stromboli seem to be more susceptible to variation due to background variables. Significant although weak[3] associations with age ($F=2.6$, $p<0.05$), duration of the stay on the island ($F=5.8$, $p<0.01$), and number of different information sources consumed[4] ($F=2$ $p<0.05$) are recorded and shown in Figs. 3, 4 and 5. The three features associated with the perception of probability can be related to different ways of accessing information. Age is associated with the accumulation of past experiences and memories, which shape an individual's understanding of probabilities. A longer duration of stay on the island provides increased opportunities for encounters with residents, excursion guides, or informative signage, exposing individuals to valuable insights about potential hazards. Additionally, accessing a greater variety of media sources enables individuals to obtain information that may not be readily available to the general public, including specialized knowledge or data that can impact the perception of probabilities related to specific events or risks.

[3] Values of ^{2} for all three associations were between 0.01 and 0.03 (see Appendix B).

[4] Mean = 4.3; S.D. = 1.9.

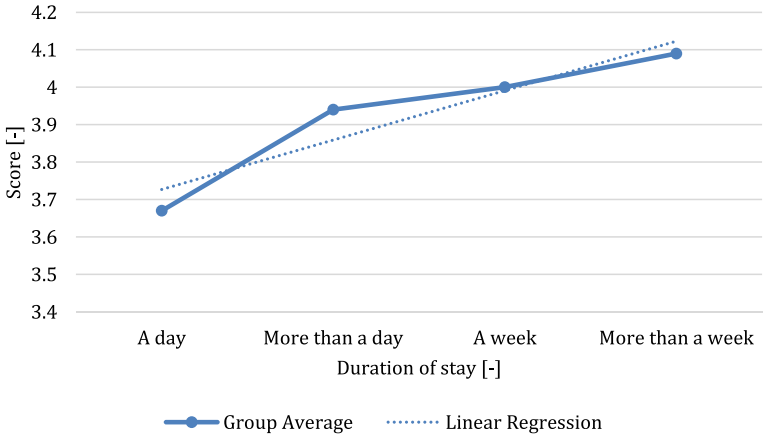

Fig. 4 Average Perception of the probability of a tsunami hitting Stromboli by duration of stay

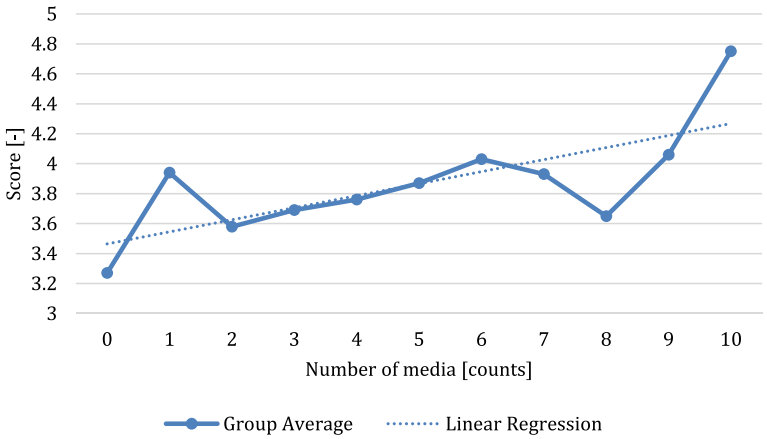

Fig. 5 Average perception of the probability of a tsunami hitting Stromboli by media consumption (quantity)

To further analyze the relationship between media consumption and perception of probability respondents were grouped based on the media indicated. Only readers of scientific/academic journals (n = 99) have been found to have on average a significantly higher perception of the probability of a tsunami in the Mediterranean Sea (Mean = 3.3, S.D. = 0.9, F = 10.8, $p < 0.01$) and in Stromboli (Mean = 4.1, S.D. = 0.8, F = 10.9, $p < 0.01$). Respondents who indicated encyclopedias as information sources (n = 53) have a higher perception of the probability of a tsunami in Stromboli (Mean = 4.2, S.D. = 0.7, F = 7.4, $p < 0.01$). The respondents in these two categories hardly coincide (see Appendix B).

5.2 Expected intensity

Estimation of physical magnitudes (height; inundation length) is challenging and large portions of respondents are unable to guess potential height and inundation length. When the respondents are asked the height at which a tsunami could be potentially dangerous to people the frequency of invalid responses decreases to 6.0% (see Table 6). Tables 4 and 5 show the highest frequencies on the largest values on the scales for physical magnitudes, revealing tsunami representations that are inflated towards large events. The 2002 event made such estimates entirely plausible, and they stand for a correct representation of Stromboli's ability to generate tsunamis.

Media consumption, educational attainment, duration of stay, nationality, and gender appear to be mildly associated with the perception of the phenomenon's intensity. This affects both the frequency of "I don't know" responses and the ability to construct representations suitable to the context (see Annex B). Men are more certain of their judgements and show the well-known tendency to underestimate the surrounding risks (Terpstra & Lindell 2013; Lindell et al. 2015; Buylova et al. 2020), and distinguishing respondents in Italian and foreign tourists highlighted differences in physical estimations, with foreign tourists' estimates being higher, probably attributable to the overall higher education and media exposure of this portion of the sample. The duration of stay on Stromboli

Table 4 Frequencies of response to "If a tsunami wave were to hit the island of Stromboli, what height could it reach?"

Response	n	%
Less than 50 cm	8	1,1
Between 50 cm and 1 m	21	3,0
Between 1 and 3 m	147	21,0
Above 3 m	367	52,5
I don't know	156	22,3
Total	699	100

Table 5 Frequencies of response to "If a tsunami wave were to hit the island of Stromboli, how far from the shore could the water reach?"

Response	n	%
A few meters	34	4.9
A few tens of meters	217	31.0
A few hundred meters	303	43.3
I don't know	145	20.7
Total	699	100

Table 6 Frequencies of response to "In your opinion, what height does a tsunami wave need to reach in order to be dangerous to people near the shore?"

Response	n	%
Less than 50 cm	37	5.3
Between 50 cm and 1 m	146	20.9
Between 1 and 3 m	300	42.9
Above 3 m	174	24.9
I don't know	42	6.0
Total	699	100

significantly affects perception accuracy; longer stays allow one to become acquainted with the island's morphology, and tourists staying over a week make what they deem to be more precise estimations, with 53.1% estimating potential inundation length in ''tens of meters'' (see Annex B).

Educational attainment is also effective in shaping perceptions of tsunami intensity. Respondents with tertiary education more frequently estimate a potential height above 3 m (53.9%), as do those with post-tertiary degrees (64%). To note, in other studies conducted with the previous version of the instrument, educational attainment influenced the perception of probability but no influence on intensity estimations was recorded (Cerase et al. 2019; Cugliari et al. 2022). Along with high educational attainment, the number of information sources also indicates familiarity with concepts related to the risk. Respondents grouped based on their estimations differ significantly in the average number of media consumed. A varied media diet allows access to scientifically accurate information that is later used to characterize hazardous scenarios such as tsunamis correctly. This particularly shows when respondents are asked *'What height does a tsunami wave need to reach in order to be dangerous to people near the shore?':* the groups of those who answered '*Less than 50* cm and *'Between 50* cm *and 1* m consume on average more media than the others (Appendix B).

The sample's answers to this last question highlight a tendency to underestimate the harm posed by smaller events (Table 6), which we know from probabilistic hazard modeling to be the most frequent (Basili et al. 2018). The challenge that this poses to risk communication is to tune tourists' perceptions with the reality of Stromboli tsunami risk. To reduce the possibility that warning signals will be ignored, tourists need to be aware that volcanic-induced tsunamis in Stromboli very rarely can reach the magnitude of the 2002 event (that still stands as proof that very big tsunamis are possible in the area) but nonetheless, they pose a significant threat to their safety in any shape they can assume.

5.3 Knowledge of the alert system and behaviors

The survey aimed to capture insights into individual coping abilities regarding risk-related behaviors. Interestingly, only 36.7% of respondents claimed to know what actions to take during a tsunami, indicating an overall low perception of self-efficacy in an emergency. Further analysis revealed that within this group, 64.3% planned to move uphill from the shore, while only 32.1% mentioned awareness of evacuation routes and waiting areas on the island. When unprompted, only a little over 12% referred to evacuation routes and areas in their emergency plans.

Regarding the information received by tourists on-site, the survey included closed-answer items assessing their knowledge of evacuation routes and the island's acoustic warning system. Results showed that just 31.47% were aware of the evacuation routes. Knowledge of the acoustic alerts was investigated in a subset of respondents (n = 363), similarly only 37.2% stated awareness of such alerts, and of those who knew only 39.7% could correctly match the signal with the corresponding phenomenon.

Self-efficacy and awareness of the escape routes were combined in a typology, outlining four distinct tourist groups based on their coping abilities in dealing with tsunami-related hazards. Each group represents a different degree of preparedness, shedding light on their informational needs for effective communication strategy planning (see Table 7).

The first group will be referred to as the highest degree of preparedness to which the other groups should converge. Tourists in the first group are both *Aware and Prepared*

Table 7 Tourists' Typology scheme

	Are you aware of the evacuation routes and assembly areas?		
		Yes	No/I don't know
[…]do you know what to do to ensure your safety?	Yes	Aware and Prepared (19.6%)	Prepared but Unaware (17.2%)
	No / I don't know	Aware but Unprepared (11.9%)	Lacking Both Knowledge Sets. (51.4%)

since they are aware of the measures in place on the island and of what is expected from them (19.6%). Tourists in the second group are *Prepared but Unaware* and rank just above the others since they state they know what to do when the tsunami comes (17.2%). The third group is *Aware* of escape routes *but Unprepared* to take coherent actions in case of an emergency (11.9%), while tourists in the last one are *Lacking Both Knowledge Sets* and represent the largest part of the sample (51.4%). The presence of such a large group unaware of the protocols and the behaviors tells what is needed about the urgency of the intervention.

To better understand the characteristics of each group, a comparison analysis was carried out with the independent-sample proportions procedure included in IBM SPSS ver. 28. The technique allows to compare different groups, taking one as the baseline, according to the proportion of individuals exhibiting certain key features. The difference in the proportion of such individuals can be used to describe and characterize the groups according to the features that are most (or least) present. Given that our groups represent different degrees of coping abilities, such descriptions can be used to understand the features that aid or obstacle their development.

The chart in Figure presents the proportions of (a) foreign tourists; (b) tourists above 35 years; (c) tourists who stay only a day on the island; (d) tourists who consume more media than the average; (e) tourists with a high perception of the probability of a tsunami hitting Stromboli (Figure 6).

Setting the *Aware and Prepared* as the reference group, we can observe how the other groups differ from this one in terms of proportion of individuals presenting those key features. The distribution of foreign tourists in the four groups pretty much follows the distribution of the overall sample, with the only significant difference of the *Unaware and Unprepared* groups, in which Italian tourists seem to be relatively more present than in the others. Age and length of stay are more characterizing factors, with wider differences between groups in the proportion of adults (above 35 y.o) and of tourists who stay only one day. The first one highlights the link between preparedness and age and tells us that the two least prepared groups are mostly young adults. The second confirms the time dependency of the access to useful information and is closely related to the level of awareness of the island risks: the two groups with the highest awareness are the two groups in which tourists staying on the island one day or less are a minority. The last feature to discriminate between all four groups is the perception of the probability of a tsunami hitting the island, providing a clear representation of the link between preparedness and risk perception

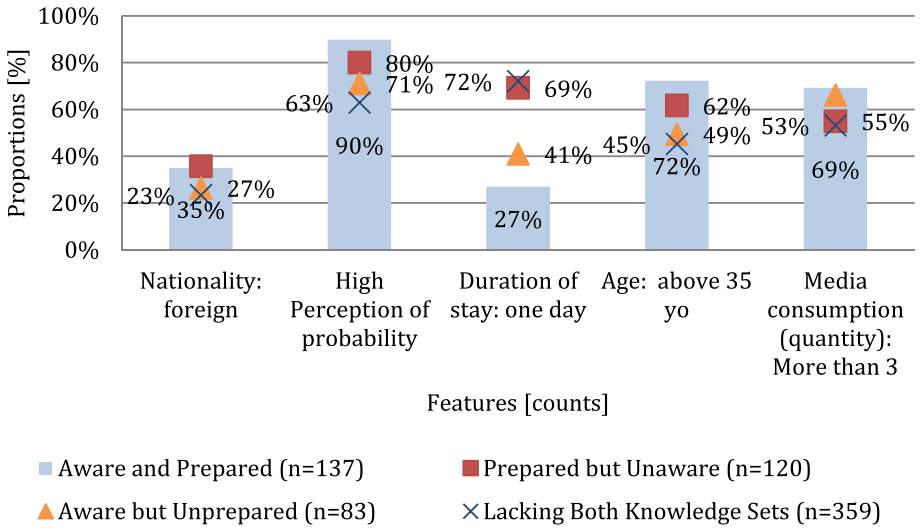

Fig. 6 Independent-Samples Proportions. Base-line group *Aware and prepared* (bold). Only values that represent a significant difference from the baseline are shown (p-value < 0.05)

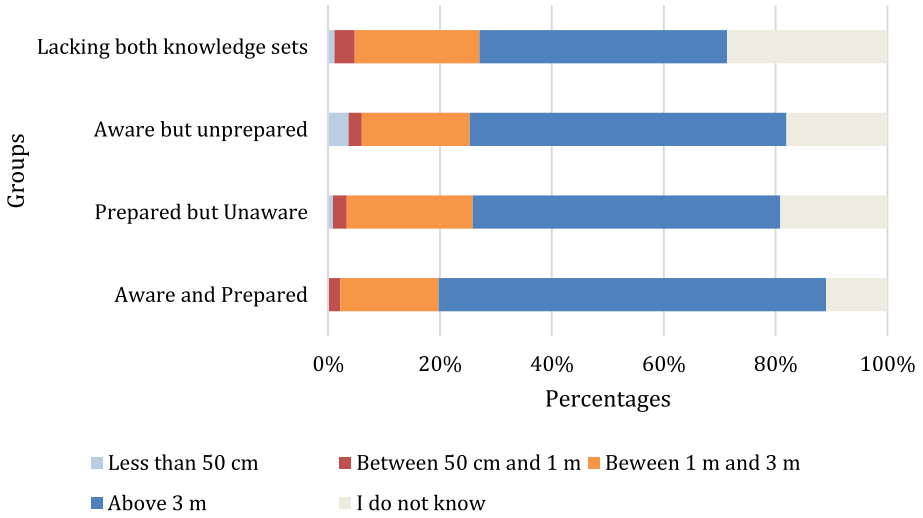

Fig. 7 Representations of the tsunami height by group

(Fitzpatrick et al. 1991; Becken and Hughey, 2013). Lastly, how the groups differ in media exposure shows that information acquired through the media influences awareness levels but does not seem to affect preparedness and self-efficacy perception in emergencies (i.e., knowing what to do, or at least perceiving to know it).

Less pronounced are the differences in physical estimations, with the biggest difference among the groups registered in the degree of uncertainty (see Figs. 7 and 8). Tsunami representations appear skewed towards events of big magnitude regardless of the group even though the chance of encountering small tsunamis is higher. Meanwhile, the hazard posed

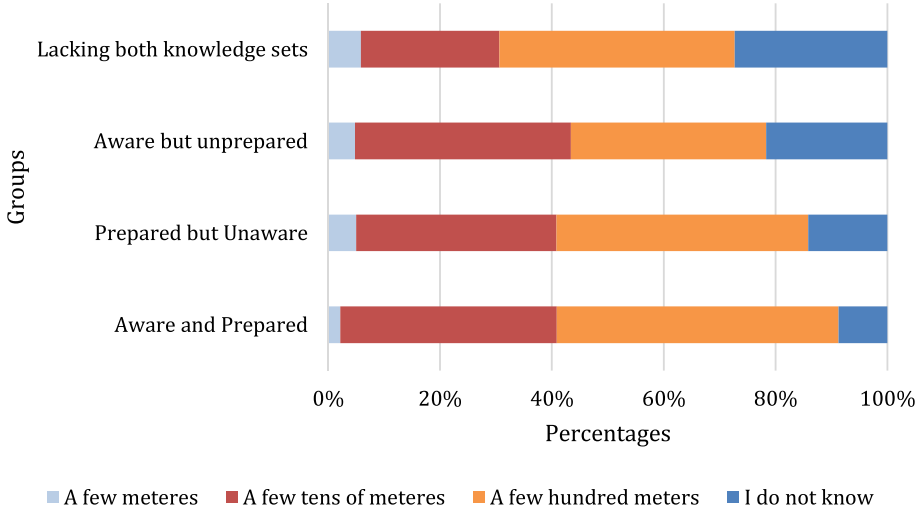

Fig. 8 Representation of the ingression length by group

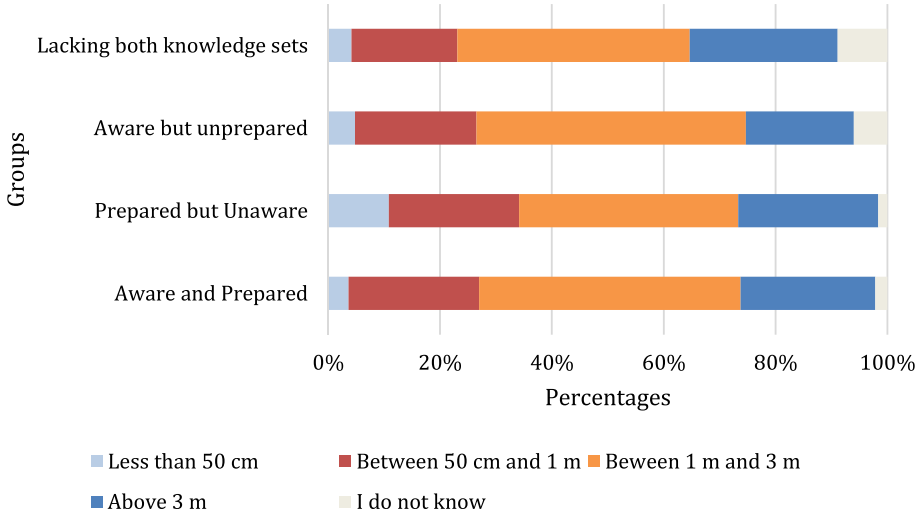

Fig. 9 Representation of the height potentially harmful to people by group

by tsunamis to people is strongly underestimated: regardless of the group, harm is perceived mostly from tsunamis of at least 1 m in height (see Fig. 9). These common representations of tsunamis across the four groups can be sustained by often exaggerated mediatic portrayals of tsunami events (Cerase et al. 2019). As expressed in par. 4.1 and 4.2, the more varied the interviewees media diet, the more precise their representations become. This is probably due to a different degree of precision in the description of the events the more one ventures into consuming more specialized media. But a varied media diet, especially on such topics, is often a privilege of the few.

6 Conclusions

The data collected from the survey allowed us to answer basic questions (cf. Para 2.4) that will orient and guide further strategies for tsunami risk communication in Stromboli.

As for tourists tsunami risk perception on the island and the individual factors that affect such perceptions (RQs 1,2,3), Stromboli is rightly recognized as exposed to a higher probability of being hit by a tsunami than the rest of the Mediterranean coasts (cf. Para. 4.1, Tables 2 and 3) and the possibility of a tsunami greater than 3 m in height or that could inundate for the island for hundreds of meters is well known (cf. Para. 4..2, Tables 4 and 5). What particularly stands out is a spread characterization of tsunamis as dangerous for people only when they reach 1 m or above, with a substantial underestimation of the dangers posed by less spectacular but equally dangerous (and more frequent) events (cf. Para 4.2, Table 6). The assessment of probability varies, with increased perception according to one's age and the duration of the stay, and varies with one's media diet (both the quantity and the quality of media consumed). Physical dimensions are more difficult to estimate and estimates vary according to exposure to information attained through education, media, or longer stays on the island (Table 7).

As for awareness of the procedures (RQ4) the survey highlighted the lack of current communication methods for alerts and risk behaviors: over half of the surveyed tourists lack knowledge about evacuation routes or how to respond to a tsunami; sixty-three percent of those who were asked were unaware of the presence of acoustic alerting signals on the island, and even those who recognized them struggled to recall their meaning (cf. Para 4.3). Differences in proportions of key features between groups characterized by different degrees of awareness and preparation confirm that the preparedness of tourists on the island is dependent on the length of their stay and their assessment of the probability of a tsunami hitting the island.

It would appear that time is of the essence, and that effective communication can be achieved in Stromboli when operated through channels that can minimize the above association, tackling the most salient difference in the designed receivers. Tourism communication primarily relies on passive signs, often ineffective due to short tourist stays, while leveraging channels able to provide basic information upon arrival on the island may be regarded as crucial.

This purpose can be achieved through a variety of both technical and human means, that spans from the leveraging of cell towers to broadcast basic information on arrival to the direct involvement of the island's residents and workers as knowledge mediators. Every step from the definition of the contents of the communication strategy to specific on-site implementation must move from the assumption that community involvement is crucial. To successfully assign the role of risk communicator to the personnel of private maritime carriers that bring thousands of tourists to the island, as well as to hotel and restaurant staff and owners, they first need to agree both with the message and with the way it is carried. Institutional stakeholders (INGV, DPC, regional and municipal government) are thus called to activate a process of participatory design that guarantees to the community the space to negotiate their needs with the needs of disaster risk reduction. In this case, one key to acceptance is to ensure that the effort of informing incoming visitors of the risks will not translate into reduced tourist presence.

Additional space for negotiations will be certainly explored during the scheduled focus groups and semi structured with the resident population. Meanwhile, the 'Tsunami Ready program, to which Lipari Municipality adhered in September 2023, will ensure the

adoption of standardized and UNESCO-recognized guidelines and could also represent the opportunity to provide an institutional backbone to community involvement. The program contains provisions to establish a Tsunami Ready Local Committee (TRLC) with representatives from the Emergency Management Agency, voluntary and community organizations and the private sector, among others, that, besides taking part in the ordinary activities envisaged for such organ (Unesco 2022), could also represent the opportunity to bridge the gap that separates decision-makers and the local community.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11069-024-06845-1.

Author contributions All the researchers contributed to the research design. Material preparation and onsite data collection were performed by Moreschini Iacopo and Cugliari Lorenzo. Data analysis was performed by Iacopo Moreschini. The first draft was written by Iacopo Moreschini and Massimo Crescimbene. All the authors provided comments and suggestions to the first draft and have approved the final version of the manuscript.

Funding Open access funding provided by Istituto Nazionale di Geofisica e Vulcanologia within the CRUI-CARE Agreement. The present research is developed as part of the agreement between the Department of Civil Protection and the National Institute of Volcanology and Geophysics which provides for the strengthening of service activities under the provisions of the art. 6 of the Framework Agreement between DPC and INGV (period 2022 2025). The National Institute of Geophysics has funded a one-year public research grant, of which the first author is the beneficiary. The study has also benefited from the financial contribution of the Italian Presidenza del Consiglio dei Ministri, Dipartimento della Protezione Civile. The publication does not necessarily reflect the position and policies of the Italian Presidenza del Consiglio dei Ministri, Dipartimento della Protezione Civile.

Declarations

Conflict of interest All the authors have no financial or non-financial interest to disclose.

Ethical approval The data are collected in an anonymous and aggregate form for statistical purposes only. Respondents are not asked for any personal data. No e-mail addresses are collected. Each respondent was however informed by the researchers of the type of survey before filling in the form. No ethical committee approval is required for the type of information collected.

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