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Telluric and Climate-Related Risk Awareness, and Risk Mitigation Strategies in the Azores Archipelago: First Steps for Building Societal Resilience

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Abstract: Islands are often considered excellent socio-ecological laboratories for testing the rapidity of global change since they experience the climate effects of sea-level rise faster than other areas. The Azores are a Portuguese volcanic archipelago located on the junction of the three tectonic plates: the Eurasian, the African and the North American plates. São Miguel, the main island of the Azores archipelago, hosts three active volcanoes, but the last significant volcanic eruption was the Capelinhos volcano on the island of Faial in 1957. Hence, the Azores offers the opportunity to assess insular risk awareness, facing both telluric and climate-related hazards. The key research question emerges from their natural situation: how does the local population perceive the threat of the natural hazards that occur in Azores? Because risks are socially constructed and depend on the uniqueness of territories, risk mitigation strategies must focus on the individual experiences of local dwellers, as a relationship between risk awareness and such strategies may be expected. To analyze this relationship, a web-based survey with a questionnaire including these variables was administered to a sample of Azoreans. The study aimed to assess risk awareness of the Azorean population and find a relationship between this and reported mitigation strategies. The results gave a preliminary insight into Azorean risk awareness of natural hazards and showed a significant positive relationship between risk awareness-raising activities and reported mitigation strategies. This is relevant information for municipalities and regional governments of areas with similar risk exposures, showing that, although risk awareness alone is not enough for measures to be implemented, it may be an important motivational first step for this to occur.

Keywords: telluric risks; climate-related risks; risk awareness; risk management; volcanic islands

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1. Introduction

Portugal is exposed to many natural hazards due to its physical location on the Atlantic Ocean and the natural characteristics of the territory. It comprises the mainland and two volcanic archipelagos, Madeira and Azores, the latter being located on the junction of three tectonic plates: the Eurasian, the African and the North American plates [1,2] (Figure 1).

A huge historical event hit the country's coasts when they suffered a tsunami resulting from an earthquake of magnitude 8.5+, the Lisbon earthquake in 1 November 1755. More recently, the last significant volcanic eruption of the Capelinhos volcano on the island of Faial, Azores, occurred in 1957. Located at the transition between a sub-tropical and an ocean climate, Portugal is also prone to drought periods and flash floods, heatwaves and wildfires, as evidenced by two devastating rural fires that occurred in central Portugal

in June and again in October 2017. The Azores have active volcanoes, such as the Sete Cidades, Fogo and Furnas on the biggest island of São Miguel (Figure 2), but these are sometimes considered to be extinct [3] by the general population, due to a lack of hazard knowledge, low volcanic risk awareness and low preparedness levels [2].

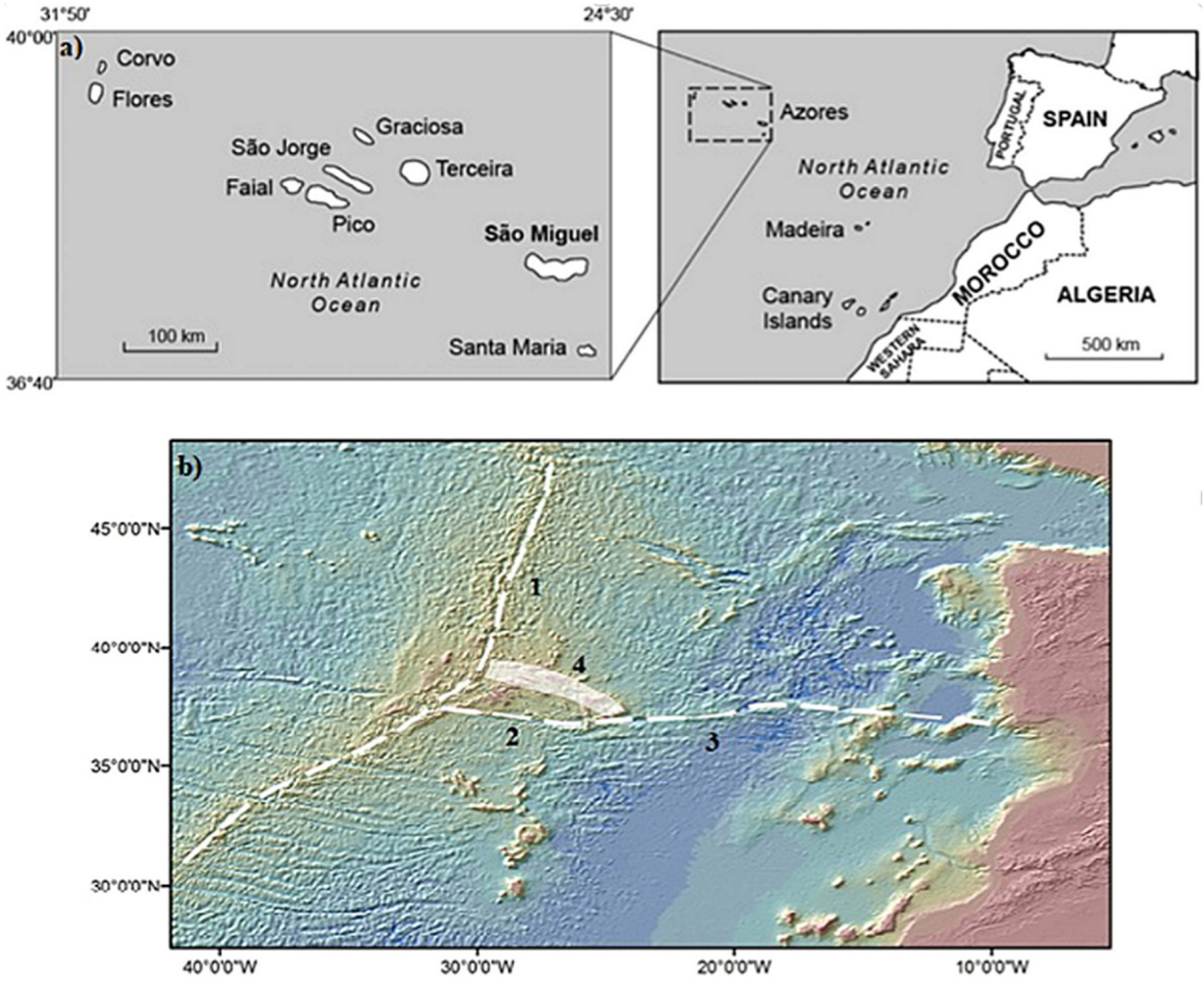

Figure 1. (**a**) Map of the Azores; (**b**) 1 Mid-Atlantic Ridge, 2 Azores-Gibraltar Fracture Zone, 3 Gloria Fault, 4 Terceira Rift. Reprinted from [2].

Understanding risk perception, and particularly risk awareness, is of major importance in risk management. It can improve efficient risk communication and inform mitigation strategies to reduce vulnerability and enhance resilience [1,2,4,5]. In light of the accelerating climate change processes, a better understanding of the role that risk perception has in shaping adaptive behavior is needed in order to cope with extreme weather events and enhance societal resilience [5]. Furthermore, not only local risk perception but also public participation is needed when implementing mitigation measures. This is particularly the case in coastal zones that concentrate population and industrial activities, and even more on small islands, such as the nine islands of the Azorean archipelago [6]. Public experience, perceptions and preparedness and the links between those components contribute to a complex process of risk management [7], the ultimate goal of which is to decrease societal vulnerability and to promote resilience.

Figure 2. Major active volcanoes on the São Miguel Island: **1** Sete Cidades, **2** Fogo, **3** Furnas.

Mitigation strategies are determined by risk perception and the evaluation of the possibility of handling this threat or coping with it [8,9]. Risk perception relates to subjective judgements of risks by individuals in the general population, and it could be described as a 'conceptual understanding' of threat; differently, risk awareness could relate to information and knowledge [10–13]. The concept of risk perception makes the process of risk appropriation multifaceted, since it proposes different logics in perceiving risks for laypeople and experts [14]. Images of risk are, every now and then, distorted. People who have had a previous hazard experience usually display a higher risk perception [15], and those who perceive higher risk are more likely to support governmental plans and take some precautionary measures [16]. However, high-risk perception and awareness do not always generate precautionary behavior [17]. For example, high seismic risk awareness did not result in concrete behavior in a comparative study between the USA, Japan and Turkey [18]. In Costa Rica, the impact of risk perception on risk awareness was detected regarding climate change and floods, but that did not result in more disaster risk reduction measures being adopted [19]. Sometimes a hazard could be considered as very serious, but people still do not to engage in precautionary behavior, as was found in the French Caribbean Island [9] and North Morocco [10]. This is also the case in the Azores, whose population, although vulnerable, appears to be poorly prepared for earthquakes [2]. Similarly, the citizens' perceptions and appraisals about extreme weather events are key for understanding climate change mitigation and adaptation of the population, since climate change creates such new challenges worldwide that it is seen as one of the major societal existential risks [5]. This scientific knowledge and its local appropriation for risk preparedness, and the differences between them, have been found to contribute to the vulnerability of local populations to natural hazards [20,21].

Based on the mechanisms related to risk mitigation strategies, and on the natural situation of the Azores archipelago, key research questions emerge that relate to: how does the local population perceives the threat of the natural hazards and climate change that occur in the Azores? Besides, does their risk awareness relate to them taking precautionary measures, and which mitigation strategies do they report taking? Risks are socially constructed and depend on the physical and cultural uniqueness of territories and must focus on the individual experiences of local dwellers [10]. The socially shared knowledge about their own territory and the local appropriation of natural hazards are of utmost importance for the citizens' preparedness for future changes. Natural hazards, such as telluric and climate related, have occurred throughout history and it is important

to examine how the local Azorean population perceives such hazards. Considering both telluric and climate-related hazards on the Azores islands, has risk awareness concerning the occurrence of natural phenomena in general, and specifically climate change, emerged among the local population? Since the island systems are excellent socio-ecological laboratories for experiments on the rapidity of global change [22,23], they are in a unique context for answering this question. Lastly, this article aims to assess the risk awareness of the Azorean population and to find a relationship between risk awareness and reported mitigation strategies, which can provide the first steps for reducing vulnerabilities and building societal resilience in the Azores.

2. Materials and Methods

2.1. Participants

A convenience sample of 201 individuals was collected, with a minimum age of 18 years old, all of them residents in the Azores archipelago. This sample was collected from an estimated 242,497 total population in 2020 (Available online: https://srea.azores.gov.pt/ReportServer/Pages/ReportViewer.aspx?%2FDemografia%2FEstimativas+da+Popula%C3%A7%C3%A3o+M%C3%A9dia&rs:Command=Render, accessed on 26 July 2020).

The spatial distribution of the sample covered seven of the nine Azorean islands; zero answers were received from the islands of Corvo and São Jorge. Participants' ages ranged from 18 to 75 years, with a mean age of 35.48 (SD = 14.18). Among the participants, 122 were women (60.7%). The sample was mostly well educated, with 33.8% of respondents without any university degree and with 23.4% of respondents having finished post-graduate studies (Master's or PhD degree). One hundred and six respondents (52.7%) were employed, and 54 respondents (26.9%) were students. Only 19 respondents (9.5%) did not work in tertiary activities, among which the main sector was education (35 respondents, 17.4%). The large majority of the sample lived in a household of a size between two to four (165 respondents, 82.1%). Seventy-three respondents (36.3%) were living with children in their household, among which 38 respondents (18.9%) lived and took care of younger children in their families. The majority resided in suburbs or residential, recently constructed areas (131 respondents, 65.1%). Lastly, the participants were asked an income question and only two did not respond to it. The annual net income of families from the sample was mainly between 15.000 and 30.000€ (37.8%), followed by the lower income (24.9%) and by the income between of 30.000 and 45.000€ (22.9%).

2.2. Instrument

Before starting, respondents were introduced to the main study objectives, and their rights in terms of data protection and ethical aspects. Based on this, their consent to participate was requested. A series of questions regarding extreme natural phenomena followed, with a set of 38 questions divided into four sections. The first part considered natural phenomena and measures of precautions. Natural phenomena questioned were: drought, flood, landslides, coastal storms, coastal erosion, sea-level rise, earthquakes, tsunamis, volcanoes, wildfires, heatwaves, and climate change. The second part dealt with risk information, place attachment and social trust. The third part of the questionnaire was dedicated to climate change and measures to address it. Finally, a section with socio-demographic questions followed. The types of questions asked were mainly close-ended (dichotomous and with a Likert 5-point rating scale), with few open-ended questions.

Risk awareness and perception were tested using question items with regards to:

(a) risk perception focused on the likelihood of the future occurrence of natural phenomena in their municipality on a 5-point Likert scale ranging from 1 (highly unlikely to occur) to 5 (it will definitely occur), for each of the ten phenomena in question [12,24];

(b) risk perception focused on how negative the consequences could be if some of the natural phenomena occur, on a 5-point Likert scale ranging from 1 (extremely negative) to 5 (not at all negative), for each of the phenomena [13,25];

(c) self-assessment of how well informed they felt about each of the natural phenomena on a 5-point Likert scale ranging from 1 (not at all informed) to 5 (completely informed) [11,26];

(d) personal experience they had with each of the phenomena (yes/no question), which could be decisive when deciding future protective measures [27], being related [28,29] or not [30] to future behavior;

(e) perceptions of climate change, through a series of questions on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), since recently climate change has been considered an existential security risk and a threat to human civilization [31,32];

Mitigation strategies proposed to participants for their assessment were:

(a) precautionary measures adopted, emergency and awareness-raising activities attended with regards to natural phenomena, on a 5-point Likert scale ranging from 1 (never, none) to 5 (always) [33,34].

(b) indirectly monetary: personal solutions they were ready to adopt in the face of extreme natural phenomena, on a 5-point Likert scale ranging from 1 (nothing) to 5 (completely) [11,13];

(c) directly monetary: preference regarding investment, when imagining that the European Union was promoting a policy to fight climate change in the coming years, they had to choose one out of six options proposed for their personal protection; and willingness to pay to insure their home against calamities resulting from climate change [11,35].

Additional questions related to variables that could have a role in the risk mitigation process:

(a) source of information: different sources the respondents use to inform themselves about extreme national phenomena, on a 5-point Likert scale ranging from 1 (not important) to 5 (totally important) [13,36];

(b) social trust: trust in each of several elements that help to reduce or avoid major damage resulting from natural phenomena and that are therefore useful in management [37,38], on a 5-point Likert scale ranging from 1 (not at all) to 5 (completely);

(c) place attachment: emotional connection that motivates a resident to maintain a relationship with a particular place [39,40], on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree);

(d) environmental identity: to control the degree to which the respondents identify the importance of their environment and their environmental concerns [10,41], on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree).

(e) demographic and socio-economic information: various questions on gender, age, education, profession, family composition, housing, and income.

Finally, the readers should note that not all questions from the questionnaire were analyzed for the purpose of this paper. The main questions in this analysis related to risk perception for each of the ten proposed phenomena (future occurrence, severity of consequences and information self-assessment), to awareness of the climate change phenomenon, and to precautionary measures and mitigation strategies. The full questionnaire in Portuguese is available upon request to the authors.

2.3. Data and Procedure

The data were collected online, using the Qualtrics Survey Software. This approach was chosen due to the budget and time constraints of the study, although this excludes the population with no Internet access or digital skills. The data were collected in two four-week periods. One occurred between the end of October and the beginning of November 2020, and another in April 2021, due to the weak initial response. The time needed to complete the survey was close to 30 min. This preliminary survey targeted a broad general population and a convenience sample was obtained through snowball sampling techniques. This means that the final sample cannot be considered representative of the region. Nevertheless, convenience sampling is considered well-suited for exploratory, pilot studies regarding risk awareness [2,42]. The data were analyzed using SPSS software (Version 22.0).

3. Results

3.1. Risk Awareness of Natural Hazards

Participants rated the likelihood of the future occurrence of natural phenomena in their municipality as follows (Figure 3): On average, respondents considered earthquakes (M = 4.34, SD = 0.886) and climate change (M = 4.27, SD = 0.805) as the most likely natural phenomena to occur in their municipality. The least expected phenomena were wildfires (M = 2.17, SD = 1.054), droughts (M = 2.64, SD = 1.184) and tsunamis (M = 2.64, SD = 1.078). Two phenomena whose occurrence was perceived as mostly unknown were volcanic eruptions (M = 3.30, SD = 1.150) and heatwaves (M = 3.00, SD = 1.070). Among the phenomena that the respondents had mostly experienced personally were the earthquakes (29.9%), the coastal storms (25.4%), landslides (16.4%), floods (14.9%); and the least experienced were sea-level rise (3.5%), wildfire (3%), drought and volcanic eruption (1.5% each) and tsunami (zero experience). In total, 101 participants (50.2%) had personally experienced an extreme natural phenomenon, whereas 100 participants (49.8%) from the sample reported no personal experience.

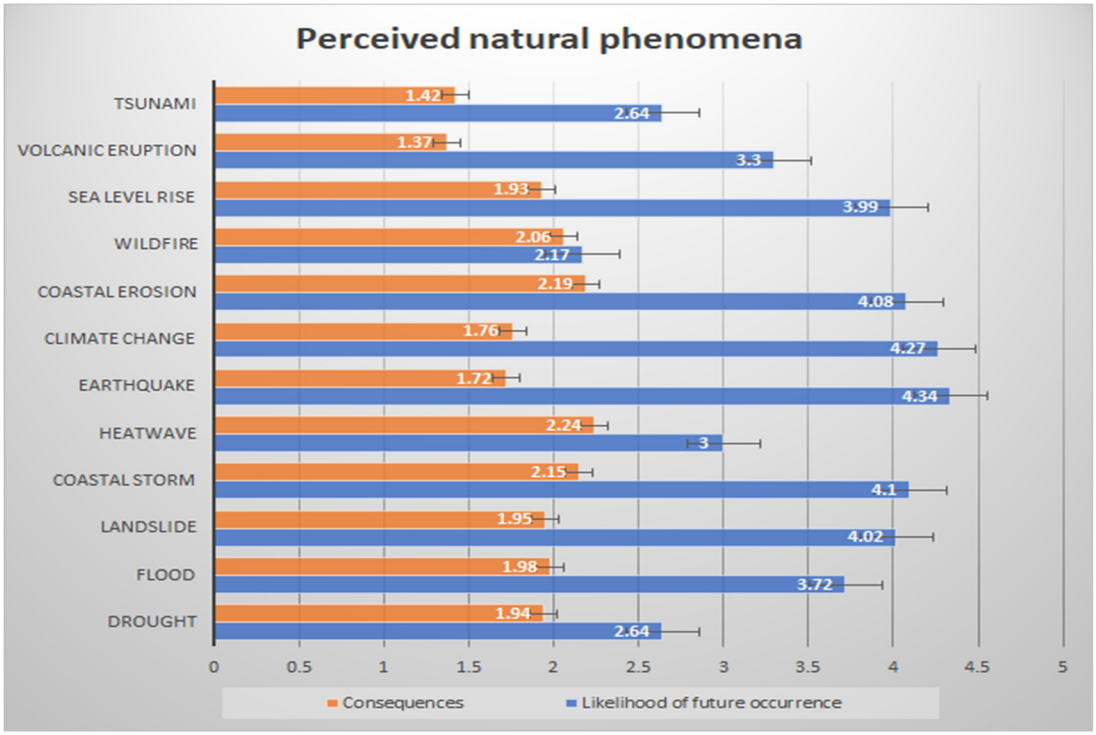

Figure 3. Perceived negative consequences and likelihood of future occurrence of natural phenomena in the Azores.

Furthermore, respondents rated the consequences of some of the natural phenomena occurring (Figure 3). The most severe consequences were assigned to volcanic eruptions (M = 1.37, SD = 0.703) and to tsunamis (M = 1.42, SD = 0.689), and the least severe wereconsidered to be heatwaves (M = 2.24, SD = 0.930), coastal erosion (M = 2.19, SD = 0.891), and coastal storms (M = 2.15, SD = 0.904), although the least severe can still be considered to have very negative consequences.

Finally, the respondents self-assessed their level of information about each of the natural phenomena. On average, they felt informed regarding all the phenomena, feeling the least informed about heatwaves (M = 2.94, SD = 0.960), and the most informed about volcanic eruptions (M = 3.44, SD = 1.099). As sources of information on extreme natural phenomena, the respondents appreciated the Civil Protection Agency the most (M = 4.65, SD = 0.639) and social networks the least (M = 3.57, SD = 1.143). Similarly, respondents expressed the highest trust in scientists (M = 4.33, SD = 0.736) and in the Civil Protection

Agency and similar public institutions involved in managing extreme natural phenomena (M = 4.28, SD = 0.744) to reduce or avoid major damage, and the least trust in social networks (M = 3.16, SD = 1.004).

3.2. Climate Change Perceptions

Respondents seemed to be quite aware of the reality of climate change. As mentioned previously, respondents considered climate change (M = 4.27, SD = 0.805) to be the second most likely natural phenomena to occur in their municipality in the future. They also felt second-best informed about climate change (M = 3.63, SD = 0.851).

In addition, the participants expressed their opinion on climate change through a series of questions. They had often heard talk about climate change (M = 4.33, SD = 0.776). They did believe that human beings with their activities had a great responsibility in relation to climate change (M = 4.50, SD = 0.775). They were also worried about the future of many animals and plants living in the seas and coastal areas and believed that they would become extinct due to climate change (M = 4.25, SD = 0.823). The participants only seemed to be a bit confused about the temporal distance of climate change consequences. They agreed that they were already experiencing the effects of climate change in the Azores (M = 4.02, SD = 0.774), but were less certain about whether the effects of climate change in the Azores would occur in the next 25 years (M = 3.47, SD = 1.105).

3.3. Reported Precautionary Measures and Mitigation Strategies

When asked about measures adopted against natural phenomena, the participants reported to having rarely implemented such precautionary behavior. They somewhat reported having taken measures (e.g., use of more resistant building materials, home automation systems, lightning rods, other technologies) to avoid damage from a possible natural phenomenon rarely that is, a few times (M = 2.67, SD = 1.214). They also somewhat reported having participated in courses on emergency, safety, fire prevention, and so forth, or adopted behaviors to avoid the damage that could result from a possible natural phenomenon (M = 2.49, SD = 1.110), and reported having rarely participated in information and awareness-raising activities concerning natural phenomena (M = 2.57, SD = 1.121).

Moreover, the participants' readiness to adopt personal solutions to face extreme natural phenomena was mixed. They were very eager to reduce the amount of waste produced and to recycle every day (M = 4.37, SD = 0.857), were somewhat ready to eat more organic food and less meat (M = 3.32, SD = 1.162) and to use public transport more often (M = 2.97, SD = 1.233), and little ready to move to another region (M = 1.75, SD = 1.063). These actions corresponded to their reported place attachment: the participants were proud to live in their municipality (M = 3.91, SD = 0.887), and they would regret it if they had to move to another municipality (M = 3.75, SD = 1.094); and as for their environmental identity, they considered themselves people who cared about the environment (M = 4.31, SD = 0.644), but they considered themselves less involved in environmental activities in their municipalities (M = 2.83, SD = 1.087).

Correlations between the risk awareness items (measures taken, course participation, and awareness activities) and the mitigation strategies items (recycling, public transport, organic food, move out) were examined, to assess whether or not there was a significant positive relationship between awareness and reported strategies. Among the correlations, presented in Table 1, participating in courses was both positively correlated with taking measures and with participating in awareness-raising activities. However, only the latter shows significant and positive correlations with mitigation strategies: with using public transport more often (0.154, $p < 0.05$) and with eating more organic food and less meat (0.184, $p < 0.01$).

Table 1. Correlations between risk awareness items and mitigation strategies items.

	Measures Taken	Course Participation	Awareness Activities	Recycling	Public Transport	Organic Food	Move Out
Measures taken		0.215 **	0.082	0.082	0.010	–0.083	0.054
Course participation			0.564 **	0.111	0.128	0.105	0.085
Awareness activities				0.073	0.154 *	0.184 *	–0.012
Recycling					0.228 **	0.280 **	–0.148 *
Public transport						0.342 **	0.059
Organic food							0.055
Move out							

** with significance < 0.01. * with significance < 0.05.

Finally, the participants expressed their preference regarding investment, when imagining the European Union's policy to fight climate change. Fourteen respondents (7%) would prefer to move to a safer place and 19 respondents (9.5%) would choose none: they would be satisfied with public compensation, even if reduced. Four respondents (2%) would choose insurance when taking out a mortgage to purchase a property. A more popular preference was to invest in infrastructures that better protected the respondent and her property, chosen 34 times (16.9%). The second most popular option was to choose insurance that protects the participant's assets and family, assessing the best option on the market, elected 61 times (30.3%). Finally, 69 respondents (34.3%) considered that, since climate change was caused by everyone's behavior, there should be compulsory insurance for everyone. More precisely, when asked for the highest amount they would be willing to spend per year to insure their home against calamities resulting from climate change, 193 respondents answered and expressed a willingness to pay of median value of 150€ (preferred over mean value due to outliers and skewed data for a range of values between 0 and 20,000€).

4. Discussion

The local population in the Azores is seemingly aware of telluric hazards, namely the threats that earthquakes pose to their lives, with the same occurring for climate change related hazards. Respondents considered earthquakes and climate change related events to be the most likely natural phenomena to occur in their municipality. The former was expected because it is the most personally experienced hazard in the archipelago. The latter, although less experienced, is also something that the population is aware of. Volcanic eruptions, however, are the phenomenon they most felt informed about and with the most severe consequences expected, while also being perceived to be among the phenomena whose occurrence is the most unknown. This perceived severity of a volcanic eruption opposes previous findings [1,3]. The participants mostly reported using the Civil Protection Agency as the source of information about natural phenomena, with the least reported source used being their social networks. They also expressed the highest trust in scientists and the Civil Protection Agency. Results indicate that the perception of occurrence is based on their experience and general knowledge about seismic hazards and the location of the archipelago, which is the case for the earthquakes. However, this perception is seemingly missing for volcanic eruptions. Similar conclusions are brought out in a study [2] regarding the São Miguel island.

All these results mean the local population is highly risk aware. The results also indicate that there is a relationship between risk awareness and reported mitigation strategies. Participating in awareness-raising activities showed significant and positive correlation with the reported mitigation strategies of using public transport more often and with eating more organic food and less meat. However, although risk awareness has been shown in many studies as not being enough to implement risk mitigation strategies (as is demonstrated by the low levels of mitigation measures reported), it remains an important first step to do so and for ultimately building societal resilience, as discussed in [4]. The question that is posed is how to reduce the gap between having hazard knowledge and

using this knowledge to implement precautionary behaviors? Could it be related to their low perceived control and self-efficacy as they are somewhat unable to overcome (structural and socio-psychological) barriers to mitigation strategies behaviors' implementation [43], associated with the geological history and nature of the archipelago? Further research should focus on such barriers and test possible differences in perception regarding two different groups of hazards, telluric and climate-related, and how this difference can be explained. The place for testing and addressing this issue could be the Azores, since both groups of hazards co-occur in this location and since islands in general are praised as "living labs" for studying the rapidity of global change [22].

Answers regarding insurance and policy preferences indicate that it would be interesting to estimate how much the respondents are willing to pay to protect their house against risks related to climate change using more precise methods than just expressing the maximum annual insurance, such as contingent valuation exercises. The willingness of the local population to invest and protect against hazards should be tested in a more robust way than that presented here, as exemplified in a Sardinian study [11], due to a lack of analysis on climate change and hazard insurance adoption at regional, national and global levels. In addition, societal resilience could be enhanced by using an analytical method that helps to interpret strengths and weaknesses to identify opportunities and threats of a system (SWOT analysis), as showcased in recent European examples [44,45].

These elements could provide useful information to decision-makers in charge of risk management and climate change mitigation measures. Improved dialogue and participatory approaches between scientists, managers' and civil society need to be enhanced. Societal risks could be tackled by an improved dialogue, collaboration, and engagement in shared activities, based on scientific and local knowledge and through the institutional and social adaptations resulting from them. The dire need to address the physical phenomena of hazards as well as how they are socially constructed, is an urgent current need. This interdisciplinary path empowers different cultural, economic, and demographic contexts with a participatory approach in the process of building societal resilience.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are openly available in OSF repository, under the URL and doi: Ivcevic, A. Azores_RiskAwareness_Ivcevic_etal2021. Available online: https://doi.org/10.17605/OSF.IO/Q678R (accessed on 7 July 2021).

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