

Different communities, different perspectives: issues affecting residents' response to a volcanic eruption in southern Iceland

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Abstract This research investigates residents' knowledge and perception of the Katla volcano and emergency response procedures in all rural and urban communities located in the eastern and southern Katla hazard zones. Using a questionnaire survey conducted in 2008, we demonstrate that there is an apparent difference between rural and urban communities' knowledge and perceptions, and identify some of the issues influencing residents' perspectives and behaviour. All rural and most urban residents have an accurate knowledge of Katla, the proposed warning system and emergency response plan. Urban residents perceived the emergency response plan to be appropriate. In comparison, rural residents did not perceive the emergency response plan as appropriate. Rural residents stated that they would personally assess the situation before deciding on a course of action independent

of the proposed plan. Livelihood connections and inherited knowledge affect rural residents' ability and willingness to comply with the recommended procedures. Factors such as hazard knowledge, sense of community and attachment to place indicate that rural residents are more resilient to volcanic hazards. Based on our findings we recommend that emergency management agencies consider issues such as personal responsibility, neighbourliness and community involvement and cooperation, to develop and implement more appropriate volcanic risk mitigation strategies. In light of the recent Eyjafjallajökull eruptions, we provide a brief discussion on the 2010 emergency response. Although our findings are Iceland-specific, our recommendations may be applied internationally to other volcanic and disaster-prone regions.

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Introduction

Volcanic risk mitigation strategies in southern Iceland have undergone revision since 2002. The motivation for this effort is the ongoing risk posed by the Katla volcano (Guðmundsson and Gylfason 2005; Russell et al. 2009; Sturkell et al. 2008, 2009) (Fig. 1). Katla is considered as one of the most hazardous volcanoes in Iceland because it produces catastrophic jökulhlaups (glacial outburst floods) and it lies in close proximity to inhabited regions on the south coast (Guðmundsson et al. 2007).

High levels of seismicity and crustal deformation during the past decade suggest that Katla is in a heightened state of activity and an eruption, without prolonged precursory signals, is expected in the near future (Sturkell et al. 2008,

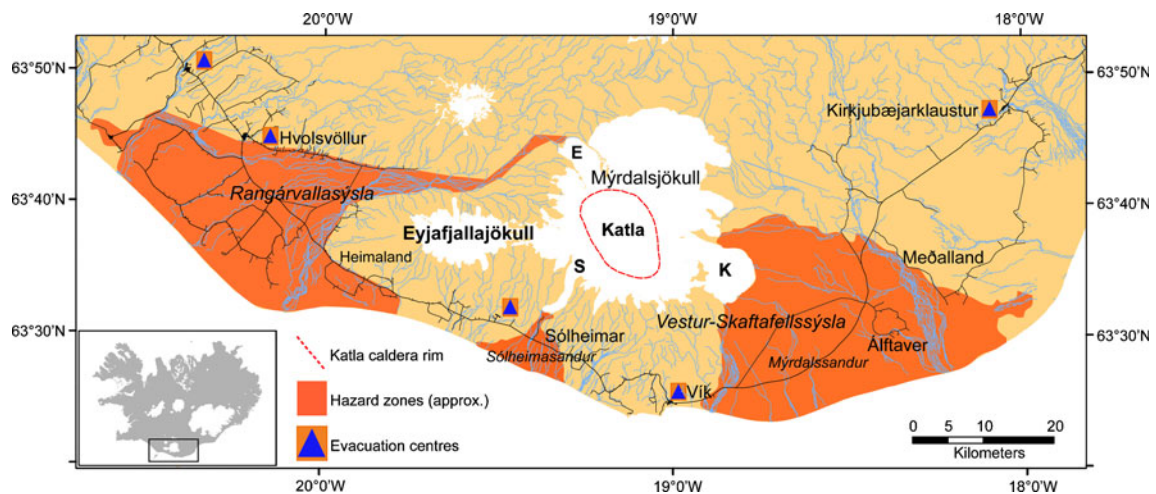


Fig. 1 Katla, Eyjafjallajökull and the Mýrdalsjökull ice cap in southern Iceland (from Bird et al. 2009). The hazard zones are based on a catastrophic subglacial eruption in the Katla volcano. The entire community of Áltaver and part of Meðalland are situated in the eastern jökulhlaup hazard zone. The entire community of Sólheimar is included in the southern jökulhlaup hazard zone and the coastal region

2009). Tremendous stress is thus placed on emergency management agencies tasked with the responsibility of developing volcanic risk mitigation strategies. For a worst-case scenario, it is estimated that there will be only 1–1.5 h to execute evacuations and road closures (Guðmundsson et al. 2008). As the possibility of a major subglacial eruption increases with time, Katla presents a significant hazard to the surrounding population (Russell et al. 2009), including the increasing number of tourists who frequent the adjacent areas (Bird 2009; Bird et al. 2010; Guðmundsson et al. 2008) and to aircraft on international flight paths that pass over southern Iceland (Sturkell et al. 2009).

Volcanic risk mitigation strategies, namely evacuation and communication plans, for the eastern and southern hazard zones were developed in 1973 by regional and national officials from the Icelandic Civil Protection Office without proper consideration of the social context of the region (Jóhannesdóttir and Gísladóttir 2010). Based on the report edited by Guðmundsson and Gylfason (2005), it appears that the recently revised plans were developed similarly. This is against recommendations in the international literature of the past decades (e.g. Barclay et al. 2008; Chester et al. 2002; Cronin et al. 2004; Dibben and Chester 1999; Mileti et al. 2004; Paton et al. 2008; Tobin 1999, among others) that are for a more thorough approach to volcanic risk mitigation, in which social investigations complement physical assessments, to reduce the risk associated with disasters.

In light of this omission, social studies were carried out to provide a more comprehensive evaluation of risk. Jóhannesdóttir (2005) conducted open, in-depth interviews with 28 residents from Áltaver and Vík in 2004 while Bird

et al. (2009) explored perceptions of emergency response procedures among residents in all communities in the western hazard zone in 2006. Jóhannesdóttir (2005) showed that Vík residents were more confident in the plan (developed in 1973) while Áltaver residents did not consider the plan appropriate to their community. Bird et al. (2009) showed that despite living in a jökulhlaup hazard zone, some residents did not perceive that their homes could be at risk, and would therefore not obey official evacuation orders.

No assessment, however, encompassed *all* communities located in the southern and eastern hazard zones, despite historic jökulhlaups, tephra, lightning and in some instances, tsunami (Guðmundsson et al. 2008) affecting these regions. In this paper we explore some of the issues that might influence residents' behaviour and their ability to respond to volcanic risk mitigation strategies.

Residents from the rural communities of Áltaver, Meðalland and Sólheimar and the urban community of Vík were the focus of the survey conducted in 2008. These communities are situated in the district of Vestur-Skaftafellssýsla. While the town of Vík might not be considered as 'urban' internationally, it is regarded as one of Iceland's 'urban nuclei' (Statistics Iceland 2010). An 'urban nucleus' is defined by Statistics Iceland (2009) as a town, village or other area with more than 200 residents living in "houses standing in the vicinity of one another". In 2008, 278 people were registered as living in Vík. We therefore classify Vík as 'urban' for this study.

In addition to the rural/urban classification, these communities may further be categorised by their vulnerability to different volcanic hazards. For example, properties

located in the rural communities of Álftaver, Meðalland and Sólheimar will be evacuated because of the risk from jökulhlaups whereas the properties in the low lying coastal urban area of Vík will be evacuated due to the risk from tsunami.

Not only is this social assessment essential in light of the conflicts revealed by Jóhannesdóttir (2005) and Bird et al. (2009) but it also: (1) provides the first investigation of residents' knowledge and perception of Katla, associated volcanic hazards and revised emergency response plans in *all* communities located in the eastern and southern hazard zones, and (2) considers residents' knowledge and perception from both rural *and* urban communities facilitating comparison between the two groups.

Of significance in assessing current risk, the police force in southern Iceland was restructured after the 2006 evacuation exercise. Amendments to the Police Act No. 90 and the Act on District Executive Power No. 92 (Lög nr 46/2006) amalgamated the police districts of Rangárvallasýsla and Vestur-Skaftafellssýsla. Consequently, the Rangárvallasýsla Chief of Police now governs Vestur-Skaftafellssýsla from Hvolsvöllur, >100 km east of Álftaver. This may have serious implications for regional risk mitigation as the Chief of Police is responsible for implementing an evacuation, and trust in such institutions is an important factor in influencing risk perceptions and response to evacuation orders (Poortinga and Pidgeon 2003).

In addition to trust, other factors play an important role in influencing people's perceptions. For example, the perception of risk and assessment of hazard by communities is influenced by their relationships with their physical and social environments (Oliver-Smith 1996). Blong (1984) suggested that rural communities that are 'closer to earth' generally perceive natural hazards more realistically than do urban communities. Conversely, Fortmann and Kusel (1990) argued that residential status had no such effect since rural and urban communities are not homogenous. Similarly, Bogner and Wiseman (1997) found no difference between rural and urban students' attitudinal and behavioural perspectives towards nature. Marotz-Baden and Colvin (1986) showed, however, that rural rather than urban residents are more likely to take control of stressful situations and adopt coping strategies.

The dynamic nature of society means that many communities are in a state of flux as people and businesses move in or out of the area and different issues spark public debate (Tobin 1999). King and MacGregor (2000) identified 'one person households' and 'newcomers to the community and migrants' among specific groups of people likely to be highly vulnerable to hazards. Risk mitigation efforts therefore need to recognise and accommodate these vulnerabilities in order to increase resilience and minimise the detrimental effects of hazards in a community. To be

resilient, communities must have the internal resources necessary to resist, absorb, accommodate and recover from the effects of hazardous events in a timely and efficient manner (UNISDR 2009; p. 10).

King and MacGregor (2000) described the required community behaviour and characteristics, which reduce vulnerability as: the ability and willingness of residents to evacuate; community involvement; an ability to access warnings, instruction and advice; having no dependents; and, general and local knowledge, among others. Also, sense of community and attachment to place are important aspects of cohesion within a society which in turn, leads to greater resilience. Therefore, examining the concepts of 'community' and 'vulnerability' as functional key elements of risk management encourages the development of more effective strategies and greater community participation (Buckle 1999).

It is therefore the purpose of this paper to investigate Álftaver, Meðalland, Sólheimar and Vík residents' knowledge, perceptions and characteristics in order to compare differences and explore how these might impact on their behaviour prior to and during a future volcanic crisis. We achieve this via a questionnaire measuring hazard knowledge, risk perception, proposed behaviour when faced with a Katla eruption and various aspects of trust and preparedness. To provide context to our research, we first describe the volcanological setting and evacuation and communication plans for an eruption in southern Iceland. Given the recent eruption of Eyjafjallajökull in 2010 and its close proximity to Katla, the background discussion is given in relation to both volcanoes.

Background

Volcanological setting

The Katla and Eyjafjallajökull central volcanoes lie approximately 25 km apart on the southern coast of Iceland (see Fig. 1). Both volcanoes are well monitored by scientists at the Icelandic Meteorological Office (IMO) and the Earth Science Institute at the University of Iceland via GPS, Continuous GPS, InSAR and optical levelling tilt stations in addition to a nationwide network of seismometers (Sigmundsson et al. 2009).

The well documented post-1500 AD historic record of Katla indicates eruptions twice a century, with the last confirmed eruption in 1918. Minor eruptions, however, which did not break the glacier surface, are thought to be responsible for small, sudden jökulhlaups in 1955 and 1999 (Guðmundsson and Gylfason 2005). Prior to 2010, the much less active Eyjafjallajökull volcano had erupted twice in the last 1,100 years, in 1612 and from 1821 to 1823. These eruptions, and crustal deformation and increased

levels of seismicity from 1991 to 1999, have either preceded or occurred in conjunction with activity in Katla (Sturkell et al. 2003).

Sturkell et al. (2003) suggest that Katla has a 5 km wide magma chamber sitting at a shallow depth of 1.5 km beneath sea level or 3 km below the topographical surface of the Mýrdalsjökull icecap. The elliptical caldera is 14 km long, 600–750 m deep (Björnsson et al. 2000) and is overlain by 590 km² of ice which constitutes Mýrdalsjökull (Björnsson and Pálsson 2008). Katla eruptions are able to penetrate the 400 m of ice cover and produce catastrophic jökulhlaups that can reach a peak discharge rate of 100,000–300,000 m³ s⁻¹ within a few hours (Björnsson 2002). Heavy tephra fallout and lightning hazards also affect communities up to 30 km from the eruption site (Larsen 2000).

In comparison, volcanic hazards associated with past Eyjafjallajökull eruptions (prior to 2010) have had less impact with only small to medium jökulhlaups (Guðmundsson and Gylfason 2005) and very fine-grained tephra deposits rarely found more than 10 km from the crater (Larsen et al. 1999). The Eyjafjallajökull volcano rises 1,651 m above sea level (Davies et al. 2010), is elongated in an east–west direction and its elliptical 2.5 km wide summit crater is covered by a 200 m thick icecap, which is also named Eyjafjallajökull (Sturkell et al. 2009). The two Eyjafjallajökull eruptions in 1612 and from 1821 to 1823 were explosive and probably occurred at the summit crater (Larsen et al. 1999). Despite the risk that Eyjafjallajökull poses to farms at the base of the southern flank of the volcano (Sturkell et al. 2003), much more interest in emergency management was given to the very active and more hazardous Katla volcano prior to the 2010 eruptions.

Unlike the previous two eruptions of Eyjafjallajökull, the 20 March 2010 eruption was located on the flank along a fissure at Fimmvörðuháls in between the Mýrdalsjökull and Eyjafjallajökull icecaps (Sigmundsson et al. 2010). This initial phase produced spectacular fire-fountain activity and lava flows, attracting many domestic and international onlookers. As soon as the “Fimmvörðuháls” flank eruption was declared over on 13 April 2010 the subglacial eruption of Eyjafjallajökull began. This explosive eruption, which commenced on 14 April 2010, first resulted in medium sized jökulhlaup flooding to the north, small jökulhlaup flooding to the south (ICP 2010) and considerable ash fall (<2 mm size fraction component of tephra) to the east and east–southeast within the vicinity of the crater (Davies et al. 2010).

The tephra that was ejected during the first few days of the subglacial “Eyjafjallajökull” eruption had a high proportion of very fine-grained ash that reached high altitudes in the atmosphere and drifted with the prevailing north-westerly to westerly winds, causing air traffic to be grounded in many countries throughout Europe (Davies et

al. 2010). The continuing eruption also produced lightning, gas emissions and lava flows within close proximity of the crater, and heavy sound blasts were heard especially to the south and east of the volcano (IMO 2010).

By 23 May 2010, eruptive activity was minimal, no further ash fall or lightning was detected and the noise from the volcano had ceased (IMO 2010). Other hazards such as lahars, rockslides and the remobilisation of ash, however, are continuing to cause havoc to areas around Eyjafjallajökull at the time of writing, and the eruption had not been declared over.

Evacuation and communication plans for an eruption in southern Iceland

Following increased seismic activity during the 1990’s in Eyjafjallajökull and Katla, the regional Chief of Police and civil protection committee requested a volcanic hazard assessment to investigate the possible threat to local communities. The hazard assessment, which was approved in July 2003, included a flood-simulation model based on geomorphological and sedimentological investigations. This model was used to assess jökulhlaup hazards for communities in the western, southern and eastern regions in relation to a Katla and Eyjafjallajökull eruption. Since Katla was determined as posing the most significant risk to the region, the jökulhlaup hazard zones were constructed based on a catastrophic Katla eruption.

Overall it was determined that the western, southern and eastern jökulhlaup hazard zones for a Katla eruption encompass approximately 1,000 km², 40 km² and 350 km² and contain approximately 1,900, 53 and 500 residents respectively (Guðmundsdóttir et al. 2010). In order to facilitate the evacuation of these residents, an engineering consultancy company was contracted to investigate travel times and traffic delays (Sigthorsson et al. 2006). This was done for a number of scenarios based on different reaction and preparation times, summer and winter conditions and, the number of travellers in the area.

Based on the information from the flood and traffic simulation models, evacuation strategies were revised and updated for communities in the southern and eastern hazard zones. To test the efficacy of the Katla plans, a full-scale evacuation exercise was held on the 25 March 2006 in Álftaver, Meðalland, Sólheimar and Vík.

If a Katla eruption is determined as imminent, the Icelandic Civil Protection Office notifies residents via a recorded voice message to their landline or a short messaging service (sms) to their mobile phone. Once received, residents in Álftaver and Meðalland will have 30 min to prepare to evacuate to Kirkjubæjarklaustur, residents in Sólheimar will have 15 min to prepare to evacuate to Vík and, residents in Vík will have 30 min to

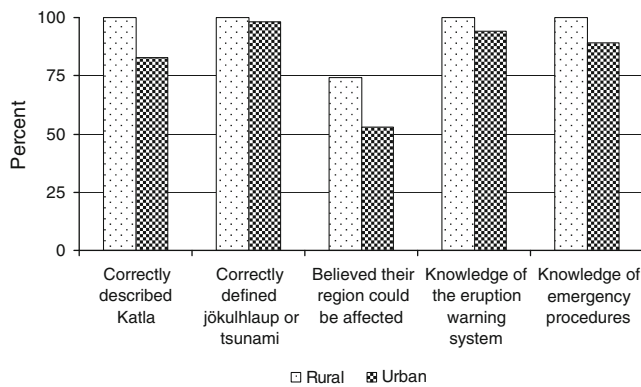


Fig. 2 Percent of participants who: correctly described Katla, correctly defined jökulhlaup or tsunami, believed the region where they live could be affected by a jökulhlaup or tsunami ($n=65$), stated knowledge of the eruption warning system and stated knowledge of the emergency procedures they need to follow

prepare to evacuate to their local evacuation centre. To aid their evacuations, residents were issued with an ‘Evacuation and Hazard Information Sign’ that lists instructions for ‘house evacuation’, ‘precautions due to subglacial eruptions’ and ‘precautions due to lightning’ (for further details, see Fig. 2 in Bird et al. 2009).

Evacuation plans for an Eyjafjallajökull eruption were not completed until the first eruption began on 20 March 2010. Our study, which was conducted in 2008, therefore focuses on Katla. In light of the recent Eyjafjallajökull eruptions, however, a brief analysis of the emergency response in 2010 is provided after discussion of our survey results.

Methods

Face-to-face questionnaire interviews

Questionnaires were administered face-to-face with local residents from April to September 2008. We endeavoured to sample one key decision maker from every permanent household located in the hazard zones in Álftaver, Meðalland, Sólheimar and Vík. Initial contact was established by phone or direct approach (i.e. door knocking). Interviews were conducted by Bird and Gísladóttir in the participants’ home or place of work. Many residents who were approached to participate in the survey had family or friendship connections with Gísladóttir.

To meet University ethical requirements potential participants were given an introductory letter before interviewing commenced. This letter described the nature of the research, what was required of the participant and the proposed use of data. Participants were given the opportunity to withdraw from the survey at any time without consequence. None exercised this right.

A total of 66 interviews were conducted with residents. This involved nine out of 10 permanent households in Álftaver, five out of eight permanent households in Meðalland, five out of six permanent households in Sólheimar and 47 out of 62 permanent households in Vík. An overall response rate of 77% was achieved. Residents’ reasons for not participating in the survey included health issues and unavailability (14%) or lack of interest (9%).

Based on the questionnaire instrument used by Bird et al. (2009), our questionnaire consisted of five sections with a total of 53 open and closed format questions. Section topics were as follows:

1. participant demographics,
2. knowledge and perception of Katla, jökulhlaup (for Álftaver, Meðalland and Sólheimar residents) or tsunami (for Vík residents),
3. knowledge and perception of emergency communication and evacuation plans,
4. personal use of media sources for acquiring hazard information (e.g. use of the Icelandic Civil Protection Office website (www.almannavarnir.is), the EWIS—near-real time earthquake web-viewer website (drifandi.vedur.is/) and the Icelandic Meteorological Office website (www.vedur.is)), and,
5. perceived personal and official preparedness for a Katla eruption, the possibility of a future Katla eruption and its effects and personal trust in hazard information.

An electronic copy of the questionnaire is available from the lead author on request.

The interviews were conducted in either English or Icelandic and responses were translated from Icelandic to English (by Gísladóttir) at the time of interview. Participants were given the opportunity for open, unstructured discussion during and after the administration of the questionnaire.

Questionnaire data were transferred into SPSS® 17.0 (Statistical Package for Social Science) and Microsoft Word®. SPSS data were coded and analysed using frequency and cross-tabulation tables and participants were assigned to either the rural group (Álftaver, Meðalland and Sólheimar ($n=19$)) or the urban group (Vík ($n=47$)). Results were assessed for statistically significant differences based on p values using Fischer’s exact (2-sided) chi-square test for 2×2 tables (e.g. yes/no response), Pearson (2-sided) chi-square test for other tables (i.e. multiple response) and independent samples t -tests (Pallant 2007). We considered $p < 0.01$ as highly significant and $0.01 < p < 0.05$ as significant. If survey participants (total $n=66$) did not respond to a particular question, because it was not applicable to them or they chose not to (i.e. non-response), then the number of respondents (n) is given for that question.

All data were transferred to *QSR NVivo 8*® for coding in order to compare, contrast and link open-response data with closed-response. All qualitative data was coded by tagging sections of text which related to specific categories. These categories relate to issues raised by Jóhannesdóttir (2005) and Bird et al. (2009). Links between open-response answers, additional comments and closed-response answers are identified and presented for each section in the results. The results are then challenged or supported by the broader literature on volcanic risk perception and behavioural response in the discussion section which follows the results.

Results

Nearly all residents offered us a warm welcome and many were very appreciative of being given the opportunity to share their thoughts and opinions. When informed of the questionnaire's topic, many residents declared "*I don't know anything about Katla*". However, many homes contained landscape paintings and photographs of Mýrdalsjökull and the surrounding region.

Questionnaire interviews took an average of approximately 45 min to complete. However, residents who had recently moved into the region took approximately 20 min while those who had lived in the region for many generations discussed Katla for almost 2 h. All participants (except one urban) had lived in Iceland most of their life and Icelandic was the main language spoken in the home. A summary of participant demographics is given in Table 1.

There is a highly significant difference ($p < 0.001$) between the two groups' occupations. All rural participants are farmers compared to only 4% of urban participants. Also, all rural participants moved to their current residence in the hazard zone prior to the 2006 exercise and 74% settled prior to the development of the last evacuation plans in 1973. In comparison, 13% of urban participants moved to their current residence after the 2006 exercise and only 38% had lived there prior to the 1973 plans. Consequently, a significant difference was found between the length of time residents had lived at their present address ($p = 0.023$).

When asked about Katla, many participants from both groups stated '*I never think of Katla*' and then continued to describe their experiences of unconfirmed eruptions in 1955 and 1999 and relay stories from friends and relatives who experienced the 1918 eruption. Within this survey, participants classed as having an accurate knowledge of Katla described the last confirmed eruption in 1918 or the possible eruptions in 1955 or 1999 and, the frequency of Katla eruptions as 1, 2 or 3 times per century. Some participants were counted as having answered correctly if they mentioned just one of the above eruptions but also provided detailed information about other aspects of Katla.

Table 1 Demographic details of rural and urban participants. All data are given as a percentage. Some sections do not equal 100% due to rounding

	Rural	Urban
Participant age:		
▪ 18–30 yrs	0	11
▪ 31–50 yrs	32	21
▪ 51+ yrs	68	68
Distance of house from river/coast:		
▪ 0 < 2 km	47	98
▪ 2 ≤ 5 km	53	2
Number of generations lived in region:		
▪ 1st	11	32
▪ 2nd	5	9
▪ 3rd +	84	60
Number of adults living at this address:		
▪ 1 adult	26	36
▪ 2+ adults	74	64
Number of children living at this address:		
▪ 0 children	53	70
▪ 1+ children	47	30
Highest level of education achieved:		
▪ Up to high school	79	66
▪ University degree or higher	0	15
▪ Other	21	19
Occupation:		
▪ Farmer	100	4
▪ Other	0	96

All rural residents accurately described Katla (Fig. 2) and all rural residents reported inherited local knowledge or direct experience of the 1955 or 1999 jökulhlaups. Participants whose relatives had resided in the region for several generations referenced other events such as the 1625 and 1755 Katla eruptions. Only one urban participant who had taken up residence in Vík after the 2006 exercise accurately described Katla. See Appendix A (Online Resource) for participants' comments relating to their perceptions of Katla.

Almost three-quarters (74%) of rural participants believed their region could be at risk from jökulhlaup whereas slightly more than half (53%) of urban participants believed their region could be at risk of tsunami. All Álftaver residents believed their region could be at risk while two Sólheimar and one Meðalland resident did not perceive a risk. The remaining rural participants stated 'don't know'. See Appendix B (Online Resource) for urban participants' comments explaining why, despite living in the defined tsunami hazard zone, they do not believe their region could be at risk.

Overall, nearly all participants knew of the eruption warning system and were aware of the emergency procedures they should follow if a warning is issued. Three out

of five of the urban participants who were not aware of the emergency procedures were new residents. Many urban residents expressed concern about the need to educate new residents on emergency response procedures. One participant echoed the sentiment of many by stating: “*It is not very good as there are many new people who are not sure. This should be part of welcoming new residents to Vík.*”

There is a highly significant difference ($p=0.003$) between the two groups’ responses to the open question ‘If a hazard warning is issued what would you do?’ Urban participants are more likely to follow the recommended procedures than are rural participants (Table 2). Many Álfaver residents stated they would go to Herjólfsstaðir, a local farmhouse located on higher ground, because they believed they would be safe there, the community could remain together and they would be in a position to tend their livestock if needed. Other comments are listed in Appendix C (Online Resource).

The majority of participants from both groups would call either 112 (the Icelandic emergency services number), the police or a neighbour in the event of an unannounced Katla eruption. However, nearly a quarter of participants chose the option ‘other’. See Appendix D (Online Resource) for participant explanations.

Table 2 Participants’ ($n=65$) predicted behavioural response to a hazard warning and a Katla eruption and perception of risk. All data are given as a percentage. Some sections do not equal 100% due to rounding

	Rural	Urban
If a hazard warning is issued,% of participants who would:		
• Follow procedures	58	91
• Other	42	9
If a Katla eruption commenced without warning,% of participants who would:		
• Call 112, police or neighbour	63	51
• Wait for text message or phone call	5	13
• Turn on radio, TV or internet	0	9
• Other	26	23
• Don’t know	5	4
% of participants who believe the following hazard poses the most serious risk if Katla erupts:		
• Jökulhlaup	53	17
• Ice blocks	6	0
• Lightning	39	15
• Tephra	26	20
• Poisonous gases	0	4
• Lava	0	2
• Tsunami	0	49
• Earthquake	0	2
• Don’t know	0	4

More than half of rural participants (i.e. those living in a jökulhlaup hazard zone) perceived that jökulhlaup will pose the most serious risk to them, while nearly half of urban participants (i.e. those living in the tsunami hazard zone) perceived tsunami will pose the most serious risk to their region.

The results show that in addition to jökulhlaup, rural participants perceived lightning hazard as a serious risk. One participant remarked: “*Jökulhlaup [as the most serious] but lightning can be very serious. Lightning is greatly feared in this region...Even though tephra was quite small the lightning was so severe that it looked like the middle of the day even though it was night in October [during the 1918 eruption].*”

Tephra was also considered a serious risk by both groups. Participant comments included:

- *Tephra, I’m not so afraid that we are in real danger but it may become completely dark and this would be a huge mental strain to deal with. I know of farmers who were out in the complete dark and they had to use the fence to find their way [back to the house during the 1918 Katla eruption]. This would be very difficult to deal with (rural).*
- *I rank tephra as 1, 2 and 3 (urban).*

Of those participants who took part in the 2006 exercise, 57% of rural and 90% of urban participants were positive about its implementation (Fig. 3) and the chi-square test indicates that there is a significant difference ($p=0.017$) between rural and urban responses to this question. Many Álfaver residents again stated that they would evacuate to Herjólfsstaðir rather than drive to Kirkjubæjarklaustur. One participant added: “*It’s like we are driving right into her [Katla’s] mouth (see Fig. 1).*” Other feelings expressed by Álfaver participants in relation to the evacuation exercise are listed in Appendix E (Online Resource).

Sólheimar participants’ mixed feelings towards the exercise arose because only one participant received the actual evacuation message. These participants were working away from their landlines and inadequate reception prevented the sms message from reaching their mobile phones. The evacuation message also failed to reach one Meðalland participant, while another expressed concern about releasing livestock.

When asked if 15 or 30 min was enough time to complete the list of instructions on the evacuation and hazard information sign several participants residing in Sólheimar and Vík revealed that they do not possess this sign. Those participants in Vík had all moved into the area after the evacuation exercise in 2006.

A highly significant difference ($p<0.001$) was found between the two groups’ perceptions of the evacuation plan. Of the rural participants who responded positively

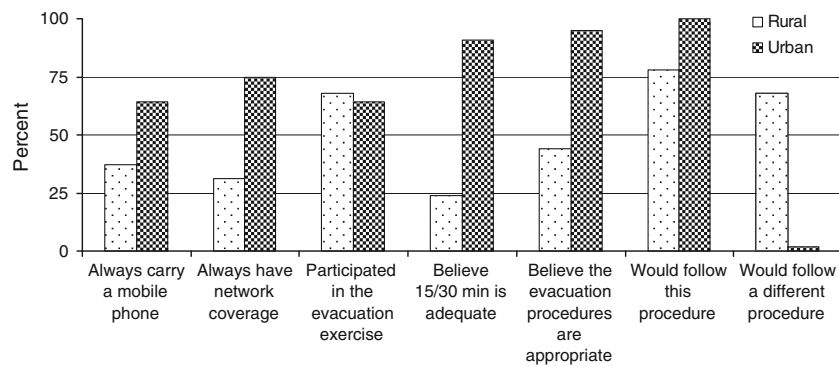


Fig. 3 Percent of participants who: always carry a mobile phone, always have network coverage to their mobile phone, took part in the evacuation exercise, think 15 or 30 min is enough time to prepare to evacuate ($n=65$),

think the evacuation procedures are appropriate ($n=64$), would follow this procedure if there was a real evacuation ($n=64$) and would follow a different procedure if conditions were not favourable ($n=64$)

toward the plan, only one participant was from Álftaver. Most (74%) rural and nearly all (97%) urban participants would follow the evacuation procedure during a real emergency. Of the rural participants who would not, five were from Álftaver. Only 32% of rural participants stated they would still follow the proposed plan if weather conditions were bad. This included not one participant from Álftaver. In comparison, 93% of urban participants would still follow the plan.

There is a highly significant difference between the two groups' responses to each of the closed questions 'would you follow this procedure if there was a real evacuation' ($p=0.006$) and 'would you follow a different procedure if weather conditions were bad' ($p<0.001$). Comments from rural participants in relation to their decision to not follow the proposed emergency plan during unfavourable conditions are listed in Appendix F (Online Resource).

Very few participants from either group accessed hazard information from the Icelandic Civil Protection Office website (rural: 11%; urban: 15%), the EWIS—near-real time earthquake web-viewer website (rural: 37%; urban: 36%) or the Icelandic Meteorological Office website (rural: 37%; urban: 47%). However, 90% of rural and 94% of urban stated they had followed discussions about Katla in the media. The most popular media sources were radio (rural: 94%; urban: 84%) and television (rural: 88%; urban: 80%) (Fig. 4). The chi-square test shows there is a highly significant difference ($p=0.009$) between the two groups' use of newspapers. Rural participants are less likely to rely on newspapers as a source of information because "we get them so late so the news is old". The groups' responses to other media sources did not indicate any significant difference.

A five-point response format was used to measure the remaining questions and independent sample t-tests were performed on each in SPSS. Overall, participants perceived themselves as being less prepared for a Katla eruption than they considered the Icelandic Civil Protection Office and

regional public officials to be (Table 3). There is a significant difference between the groups' perceptions of personal preparedness. Overall, urban participants rate themselves as more than moderately prepared whereas rural participants rated themselves as less than moderately prepared. Participant comments regarding preparedness are listed in Appendix G (Online Resource).

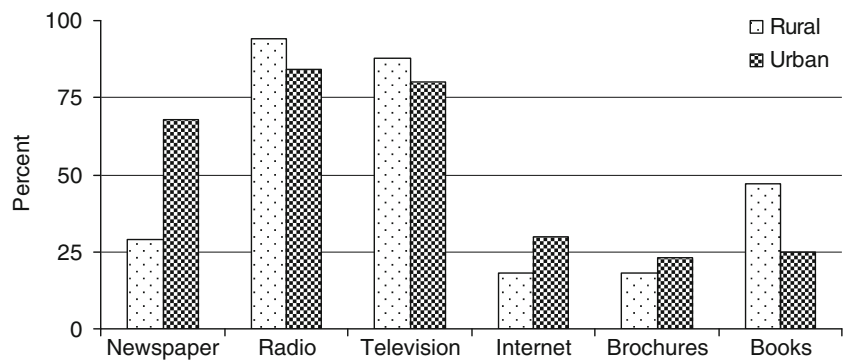
Although many participants perceived that it is unlikely there will be a Katla eruption in the next 10 years there is a highly significant difference between the groups' perception. Participants from both groups supported their belief that Katla is unlikely to erupt in the next 10 years by citing "Krukksspá". Krukkur was a fortune teller who predicted (in Krukksspá) that Katla would not erupt after certain circumstances had been met (all of which have occurred). Other residents stated that "she has released herself" during either the unconfirmed 1955 Katla eruption or the neighbouring Heimaey eruption in 1973. Comments in relation to these questions are listed in Appendix H (Online Resource).

Overall, rural participants have the greatest trust in information provided by scientists whereas urban participants have the greatest trust in information provided by the Icelandic Civil Protection Office. The results show there is a highly significant difference between the groups' trust in information from the Icelandic Civil Protection Office and a significant difference between the groups' trust in information provided by local police and the media. Urban participants' sentiment was "we have to have trust in these people", and one participant echoed the opinion of many by stating: "I can never expect it completely. We are aware that they are just people and that they will do their best." Other comments in regards to trust are listed in Appendix I (Online Resource).

Developments to emergency response during 2008

A meeting was held in Álftaver in spring 2008 between residents, the regional Chief of Police, the police and a

Fig. 4 Percent of participants ($n=61$) who have followed discussions in the media from various sources



member of the Icelandic Civil Protection Office. During this meeting residents were told they “had to go to Kirkjubæjarklaustur” if an evacuation was ordered. Nevertheless, one resident stated: “I am happy with the police chief following the recent meeting in spring 2008. He is really thinking of this. He believes in communicating with the locals and the local rescue team.”

He continued: “It is obvious that the police chief believes that the rescue team should have a more important role than previously stated. He is more willing to discuss options than the previous police chief.” According to this resident the current police chief stated: “the rescue team are more qualified to deal with a Katla eruption here than the police.”

Another Álftaver resident commented: “The police chief is working with us for a Plan B, especially if the weather is bad. It is not official yet but he is in favour. We will go to Mýrar or Herjólfstaðir.” These two properties in Álftaver are positioned at a higher elevation than other properties. In relation to the new plans, another resident stated: “Plan B is in the process of being completed...We are more responsible now. We are able to evaluate the situation and we could make the decision [to not evacuate to Kirkjubæjarklaustur]. The police won’t come here.”

A further resident confirmed that the evacuation procedures are now the responsibility of the local rescue team in Álftaver, of which he is a member, and that “the police are not to come into this area”. He also described changes to the plan for Sólheimar residents: “there is not enough time for them to evacuate so they are just supposed to go to higher ground”.

Regardless of some residents’ perception and the rescue teams’ increased responsibility, they still do not have the authority to determine whether residents will evacuate to Kirkjubæjarklaustur or stay in Álftaver: “In an evacuation the police chief will be in direct contact with the head of the rescue team. However, there still wasn’t a Plan B discussed at the last meeting in spring 2008. This was the first meeting [for residents] since the evacuation exercise.” This resident, who is a member of the Álftaver rescue team, also acknowledged current efforts by the regional police chief:

“I would like to commend the police chief on his work to communicate with the local rescue teams and residents.”

Apparently, another meeting was planned between the police chief and rescue teams in addition to “a meeting with residents in each town about the current set up of the police”. However, one resident expressed concern about local involvement in developing new strategies: “If they are developing any new plans they need to do it in close consultation with the local community and rescue team.”

During the survey, a town hall meeting was held in Vík on 16 August 2008 to discuss the current state of Katla. Scientific presentations were given by members of the Icelandic Meteorological Office, the University of Iceland and the regional Chief of Police. The meeting was organised in conjunction with the Icelandic Civil Protection Office and was attended by members of the local rescue teams, the Red Cross and hut wardens working in the tourist region of Þórs mörk—which is located in the western hazard zone. Unfortunately, due to lack of preparation and other community functions, very few residents attended.

Consequently, one resident, out of the four who were in attendance, criticised the timing of the meeting: “There were so few residents but then I understand that it was last minute [organising] in conjunction with the scientific workshop.” This resident was very impressed with the meeting but said: “It was difficult to understand one scientist but her images were good and made it easier to understand. I found the English presentation harder to understand.”

Discussion

Our overall response rate of 77% is high in comparison with other natural hazard studies (e.g. Johnston et al. 1999). There is a possibility of non-response error but we believe this to be minimal since only 9% of households declined to participate. We surveyed a high percentage of the total population living in the hazard zone and consequently, are confident in using these results to

Table 3 Participants' ($n=65$) perceptions of officials', the Icelandic Civil Protection Office's and personal preparedness for a future Katla eruption; perceptions about the probability of a future Katla eruption and its possible effects; and, trust in information from various sources and trust in government officials who are responsible for the public's safety. The first (prepared) and third (trust) sections are ranked on a scale where 1=not at all, 2=a little, 3=moderately, 4=a great deal and 5=completely. The second section (likely) is ranked on a scale where 1 = extremely unlikely, 2 = somewhat unlikely, 3 = 50/50, 4 = somewhat likely and 5 = extremely likely

	mean	<i>p</i> value
How prepared do you think:		
- Officials (e.g. the police, rescue team) in your area are?		
• rural	3.8	0.647
• urban	3.9	
- Icelandic Civil Protection Office is?		
• rural	3.4	0.084
• urban	3.9	
- You and your family are?		
• rural	2.7	0.049
• urban	3.5	
How likely do you think:		
- There will be a Katla eruption in the next 10 years?		
• Rural	1.7	0.006
• Urban	2.5	
- Your area will be adversely affected?		
• Rural	3.7	0.306
• Urban	3.2	
- You (or your family) will be injured?		
• Rural	1.3	0.433
• Urban	1.4	
- You will suffer damage to your home?		
• Rural	2.2	0.254
• Urban	2.6	
How do you rate your level of trust in:		
- Information provided by Icelandic Civil Protection Office?		
• rural	3.6	0.008
• urban	4.3	
- Information provided by scientists?		
• rural	4.0	0.655
• urban	4.1	
- Information provided by local police?		
• rural	3.1	0.014
• urban	4.0	
- Information provided by the media?		
• rural	2.4	0.031
• urban	3.1	
- Government officials who are responsible for the public's safety?		
• rural	3.8	0.071
• urban	4.3	

develop more appropriate evacuation and communication strategies for southern Iceland. The following discussion is divided into sections which represent the key themes that emerged from our survey.

Hazard knowledge and risk perception

All rural and many urban residents described firsthand experience of the jökulhlaups in 1955 and/or 1999 and demonstrated inherited local knowledge of historic Katla eruptions. It is therefore not surprising that all rural and most urban residents accurately described Katla and displayed knowledge of the warning system and emergency response procedures. These results are exceptional particularly when compared to results of other studies. For example, Barberi et al. (2008) assessed hazard knowledge within the Red and Yellow Zones of Vesuvius and found that 45% and 33% correctly identified the year of the last eruption while only 41% and 18% of respondents were familiar with the evacuation plans, respectively.

Our result, however, is unexpected since many residents claimed little knowledge of Katla. Other studies of hazard knowledge have found that residents *overestimate* their actual knowledge (Johnston et al. 1999) or perceive themselves as *more knowledgeable* than family or friends (Lindell and Whitney 2000). In comparison, our survey suggests that residents underestimate their knowledge of hazards.

On Santorini, Dominey-Howes and Minos-Minopoulos (2004) found that residents lacked knowledge with only 7% correctly identifying when Mt Colombo last erupted. They found that despite some residents retaining hazard knowledge from previous experiences, this information was not passed on to younger generations. Within our surveyed participants, knowledge had been passed on and as such, inherited knowledge has contributed to raising awareness. We suggest that this tradition of oral history is attributable to the fact that these communities have been settled in this area for many generations. Risk related research in indigenous communities (e.g. Mercer et al. 2007; UNISDR 2008; Veland et al. 2010) has highlighted the importance of sharing local knowledge and Cronin et al. (2004) discussed linking oral histories with scientific knowledge in order to establish a common ground for communication about volcanic hazards while demystifying the science.

New residents in the urban community were lacking in knowledge of Katla, the warning system and emergency response procedures. Similarly, Lavigne et al. (2008) found that people living in their birth village usually demonstrate better knowledge of their environment whereas new migrants coming from a relatively safe area lack knowledge of volcanic hazards.

Inherited local knowledge not only raises community awareness of Katla and the associated hazards but it also affects residents' risk perceptions. For example, many urban residents did not perceive the risk of tsunami in their region *because* people in Vík who experienced the 1918 eruption did not discuss the threat of tsunami in relation to

their experience. In contrast, in Álftaver all residents demonstrated inherited local knowledge and all perceived the risk of jökulhlaup based on historic accounts. Many rural and urban residents, however, perceived the risk of lightning or tephra as more serious than that from jökulhlaup or tsunami (Table 2) based on inherited knowledge.

Behavioural response

Irrespective of knowledge and perception, rural residents described varied behavioural responses to a hazard warning whereas urban residents stated that they would follow the recommended procedure. Justifying their responses, rural residents described their obligation or duty of care to their livestock (livelihood connections) and other issues relating to inherited knowledge. It is apparent that rural residents want to protect their livestock for moral reasons as well as to sustain economic resilience. Consequently, if faced with evacuation, rural residents have an emotional dilemma about whether or not to abandon their livestock. Chester et al. (2002) also identified the importance of close links between residents and the land. They discussed how this connection has developed as a result of both active and traditional family-based agricultural ties and how it might affect residents' willingness to evacuate.

Veterinary scientists (e.g. Bryant 2008; Heath 1999) have recognised the issue of dealing with livestock during disasters and emergency management agencies, such as the Federal Emergency Management Agency in the United States, have provided preparedness advice for livestock owners (<http://www.fema.gov/plan/prepare/livestock.shtm>). These guidelines, and other related literature (Bankoff 2006; Heath et al. 2001a, b; Irvine 2006; Sorensen and Sorensen 2007), discuss the possibility of evacuating animals prior to disaster.

Livestock evacuation is typically not viable in the study region, however, because of the unpredictable nature of volcanic hazards. For example, a Katla jökulhlaup can flood to the eastern, southern or western region, and ash fall is dependent on the prevailing wind. Since tephra is of great concern during Katla eruptions and adequate shelters exist on all farms (all livestock are housed during the winter) it would be more appropriate to ensure that livestock are sheltered on high ground before residents evacuate. To avoid residents returning to attend their livestock without permission, the Icelandic Civil Protection Office should develop strategies together with local residents and the Farmers Association of Iceland to guarantee that certain residents will be able to return for short periods, whenever possible, during an evacuation.

Our results and historical reports (Bjarnason 1985; Jóhannesson 1919) indicate that residents in Álftaver

formulated what they perceived to be the best community response to the 1918 eruption. Evacuating together, residents safely relocated to a building positioned on higher ground which was not vulnerable to jökulhlaup. Many rural participants endorsed and encouraged a similar response by stating that they would evacuate to a neighbouring property on higher ground. Based on Clark (1995), King and MacGregor (2000) described concepts of cooperation and neighbourliness as important aspects of community cohesion and therefore, resilience to natural hazards. Within the rural communities, these values of personal responsibility and community involvement in emergency response procedures, in addition to community cooperation and neighbourliness, might be instrumental in reducing vulnerability.

Interestingly, residents expressed greater willingness to follow the recommended procedure when asked 'Would you follow this procedure if there was a real evacuation?' It appears that some residents do not want to openly defy officials, particularly when threatened with arrest. Haynes et al. (2008a) found that 60% of participants followed evacuation advice during a volcanic crisis on Montserrat because it was 'the right thing to do' while a further 25% followed due to legal reasons and *not* because they agreed with the advice. Bird et al. (2009; p. 260) also reported that residents took part in evacuation exercises because it was "part of their duties as an Icelandic citizen".

Perceptions of evacuation and communication plans

In general, rural residents did not perceive the evacuation plan as appropriate and if conditions are dire (i.e. heavy tephra fallout, blizzard), they would personally assess the situation before deciding on a course of action. Residents' unwillingness to evacuate to Kirkjubæjarklaustur was summed up by one participant who stated "*It's like we are driving right into her [Katla's] mouth*". In comparison, urban residents are more likely to follow recommended actions regardless of whether or not conditions are unfavourable. This could be attributed to the short distance from home to the evacuation centre in the urban community. Urban residents are not expected to leave their community and therefore attachment to place and livelihood connections are not a salient issue.

Initially, most residents would try calling the emergency number 112, the police or a neighbour for further information. This response, however, is inappropriate because telephone communications become oversaturated, leading to failure and complicating the task of emergency management agencies to gather and distribute hazard information by telephone (Bird et al. 2009; Gregg et al. 2004b). This result substantiates recommendations made by Bird et al. (2009) in relation to promoting public use of various media during a volcanic crisis. The evacuation and

hazard information sign explicitly states: “Follow all announcements on TV and radio” (see Fig. 2 Bird et al. 2009). Nevertheless, it is obvious that more needs to be done to encourage residents to first turn to media sources for further information.

Perceptions of preparedness

The difference between rural residents’ perception of officials and the Icelandic Civil Protection Office’s preparedness could be biased due to our interpretation of ‘local officials’ (i.e. the police *and* the rescue teams). When asked ‘how prepared do you think the officials in your area are?’ some residents responded separately for each, although overall, both rural and urban residents perceived the officials and the Icelandic Civil Protection Office to be more prepared than them. This perception might be influenced by emergency management agencies’ recommendations which do not assign to residents any personal responsibility. Based on the evacuation and hazard information sign, residents are only obliged to prepare *during* a volcanic crisis. Residents have not been given advice on how to prepare *prior* to an eruption.

Rural residents indicate that they believe possessing an evacuation kit equals personal preparedness. Consequently, they rated themselves as less than moderately prepared. These residents did not consider their knowledge of the recommended emergency response procedures as a form of preparedness, or the fact that they actively followed discussions in the media about Katla, or that they have a predetermined safe destination, whether it is the designated evacuation centre or a neighbouring house.

Perry and Lindell (2008) described knowledge of local alert systems and emergency response plans, identifying a safe destination, possessing masks for inhalation protection and defensive tools to protect property from tephra as simple measures to effectively anticipate, respond to, and recover from the impacts of an eruption. Consequently, our results suggest that rural residents might have underestimated their level of personal preparedness. In comparison, urban residents rated themselves as more than moderately prepared. This could be attributed to the fact that urban residents are not responsible for the well-being of livestock and the evacuation centre is within a 5 min drive of their home.

It is evident, however, that most residents are not adopting personal safety measures. Emergency management agencies must therefore inform residents that any mitigation measures implemented by them are done so to complement rather than replace personal preparation. Researchers (e.g. Gregg et al. 2004a; Lindell and Whitney 2000) have shown that when residents perceive officials to be responsible for preparedness they might be less likely to adopt self protective behaviour as compared to those residents who deem themselves respon-

sible. At present, it appears that many residents have transferred responsibility for personal safety to emergency management agencies.

This issue can be overcome if emergency management agencies engage the community and persuade them to adopt simple, effective measures *prior* to an eruption. These might include: possessing masks for inhalation protection, spare air filters for vehicles to ensure transportation during tephra fall out, and having an emergency kit on hand. Once the immediate threat of jökulhlaup or tsunami has passed and residents are allowed to return home, tools such as shovels and brooms should be readily available to remove tephra from infrastructure.

Education campaigns focusing on personal preparedness should be conducted on a regular basis and through various media. Also, the issue of educating new residents must be dealt with. In Iceland, this might easily be achieved through the National Registry Office. All people residing in Iceland must register their new address within 7 days. As a government initiative, the Icelandic Civil Protection Office could work in conjunction with the National Registry Office to distribute regionally specific hazard, risk and emergency response information kits to residents who have recently moved into a hazardous region anywhere in Iceland. Emergency management agencies should aim to develop an all-risks reduction culture by placing volcanic risk mitigation within the context of other risk-creating phenomena (e.g. earthquakes, extreme weather, climate change).

Perceptions of the probability and impacts of a Katla eruption

Perceptions varied considerably regarding the probability of a future eruption and subsequent effects, and this might be attributed to rural residents’ belief in the fortune teller Krukksspá, and that Katla ‘*released herself*’ in 1955 or 1973. Worryingly, Jóhannesdóttir (2005) reported that some residents believed that Katla was no longer active. Based on our participants’ comments, however, it appears that this might be a coping strategy rather than a form of denial. For example, many residents stated that they “*never think of Katla*” because they could not live there if they did. Even though rural residents said that they do not believe an eruption is likely in the next 10 years, they have displayed accurate knowledge and perception of hazard and risk. This cognitive dissonance, a conflict between perceptions, was also described by Dibben and Chester (1999) and Chester et al. (2002).

Dibben and Chester (1999) found that residents held beliefs that minimised their concern about a future eruption. For example, residents believed that hot springs acted as a release valve ensuring that the volcano does not reach dangerous levels of pressure. Despite these residents’

erroneous understanding, it may not be useful to try to change their perception of the probability of an eruption because such a change might provoke a feeling of unease about the future and thereby produce feelings of extreme discomfort (Dibben and Chester 1999). Also, researchers (e.g. Gaillard 2008; Lavigne et al. 2008; Lindell and Whitney 2000) have shown that preparedness and appropriate response to hazard warnings are not equated to the perception of risk.

Rural residents stated that it is ‘somewhat likely’ that their community will be adversely affected by the next eruption. However, rural residents affirmed that it is ‘somewhat unlikely’ that their homes will suffer damage and ‘extremely unlikely’ that they or their family will be injured by the next eruption. Urban residents shared similar but less extreme views. Again, this is cognitive dissonance, where residents have justified their decision to live where they do in the belief that their homes are not under threat but rather, the threat occurs elsewhere. As a result, residents feel they do not have to deal with the complexity of moving and life can go on as normal (Chester et al. 2002).

Lindell and Whitney (2000) reported comparable results in relation to residents’ perceptions of seismic hazards in Los Angeles. They demonstrated that despite participants’ perceiving the probability of a damaging earthquake as relatively high, the probability of personal property loss or injury was perceived to be relatively low. Lindell and Whitney (2000) explained that residents understood the risk to their community but did not adopt personal preparedness measures. Similarly, our results show that residents understood the risk to their community but did not consider themselves prepared. In accordance with our earlier recommendation, it is imperative that emergency management agencies focus on increasing residents’ responsibility for protecting themselves and their property (Lindell and Whitney 2000).

Level of trust

Within our study, urban residents demonstrated a high degree of trust in information provided by all emergency management agencies and are therefore more likely to accept decisions and communications from these institutions. In comparison, rural residents expressed a high degree of trust in information provided by scientists, moderate trust in information from the Icelandic Civil Protection Office and police and low levels of trust in information from the media. This finding correlates with other studies (e.g. Barberi et al. 2008; Carlino et al. 2008; Haynes et al. 2008b) which have shown that residents had greater trust in scientists than government officials.

Several rural and urban residents expressed concern regarding the restructuring of the police and how this has

affected their levels of trust in them. In this instance, it is not the police per se that residents distrust but rather the amalgamation of police districts and the repositioning of the regional police headquarters >80 km from Vík and >100 km from Álftaver. Coupled with the threat of arrest if they did not obey the evacuation orders, it is understandable that rural residents stated lower levels of trust in the police and Icelandic Civil Protection Office.

Based on our work, we believe that by establishing a working relationship, where communities and emergency management agencies engage in complementary roles in the development of risk mitigation strategies, residents will be empowered and trust will subsequently increase. When residents perceive that their concerns have been resolved through their relationship with emergency management agencies, it is more likely that they will believe in the agencies and the information they provide (Paton 2007). Not only will this increase trust, but it will also facilitate personal responsibility for adopting preparedness measures. Haynes et al. (2008b) provides further discussion on the importance of developing and maintaining a trusting relationship between emergency management agencies and the at-risk community in relation to volcanic hazards.

Residents’ lack of trust in information provided by the media is in line with that found in other studies (e.g. Haynes et al. 2008b). The media, before, during and after an event are, however, crucial for disseminating information through all channels (e.g. radio, television, internet) (Scanlon 2007) because residents will rely on multiple sources of information (Sorensen and Sorensen 2007). Given the trust residents have in the Icelandic Civil Protection Office and scientists, it would be wise to use recognised Icelandic Civil Protection Office officials and scientific experts as spokespeople to broadcast warnings and response information.

Images portraying those affected by hazards as helpless victims do little to promote personal responsibility for preparedness (Hughes and White 2005). Instead, such images promote attitudes which lead residents to become increasingly dependent on emergency management agencies. Alternatively, the media should provide an effective channel to communicate information on preparedness measures, warnings and appropriate public response, without confusing, complicating or changing the message (McGuire et al. 2009). Scientists and emergency management agencies should work closely with the Icelandic media to ensure a trusting and productive relationship prior to and during any hazardous event. Although focused on small volcanic islands, the advice and recommendations provided by McGuire et al. (2003) to improve communication during volcanic emergencies are invaluable and relevant prior to and during any crisis.

Emotional attachment and cultural connections

An intriguing point noted during both rural and urban interviews was many residents' referral to Katla as a woman and not an inanimate landform. This further demonstrates the emotional attachment and cultural connection residents have with their communities and region. According to Icelandic folktales, Katla was a wicked female cook in a monastery located in Álftaver (Guðmundsson 1996; p. 61–62):

She had magic trousers enabling her to run fast and without a break. When she discovered that a shepherd had misused her priceless belongings, she killed him and hid him in a big barrel of whey. When confronted with the revelation of her crime as the whey was slowly being used up, she fled in the trousers up to the mountains and flung herself into a dark crevasse in the ice cap. Ever since, according to tales, she avenges her fate by pouring fire and water onto the nearby regions.

Emotions are undoubtedly important explanatory factors in perceived risk and related views (Sjöberg 2007). Dibben and Chester (1999) reported that residents referred to the natural landscape as '*their land*' and that residents appeared to have an emotional attachment to the volcanic environment. Consequently, Dibben and Chester (1999) argued that the root causes of vulnerability relate to the history and development of the society. As noted in the introduction, however, community vulnerability is dependent on a variety of factors.

Community vulnerability and resilience

Using several of the factors described by King and MacGregor (2000) we can compare rural versus urban vulnerability and resilience, according to community behaviour and characteristics. For example: urban residents are more willing to evacuate; have a greater ability to access warnings, instruction and advice; and, a greater percentage have no dependent children. These factors reduce vulnerability. On the other hand, urban residents demonstrated lower levels of general and local knowledge. A higher percentage of urban residents live alone and are newcomers to the community. These factors increase vulnerability. Additionally, rural residents displayed a greater sense of community and attachment to place, factors which decrease vulnerability and increase resilience. Overall, according to these factors, rural residents should be less vulnerable and more resilient to volcanic hazards.

Our survey clearly demonstrates that emergency management agencies need to consider inherited knowledge and risk perception in conjunction with social issues inherent in

these communities. Learning from local knowledge should begin with respect for the people concerned and requires their trust (Wisner et al. 2004). The top-down method of risk mitigation which was implemented in 2006 was rejected by residents, particularly by those with inherited local knowledge and emotional and economic connections to their livelihood. Similar findings were made by Cronin et al. (2004) and as a result, considerable work was done towards adapting and applying a Participatory Rural Appraisal approach to volcanic hazard management. This approach, which incorporates scientific with traditional knowledge, enhances communication, respect and understanding between communities and emergency management agencies.

It is therefore recommended that emergency management agencies work in close consultation with, and with participation from, rural communities to enhance and exploit the abovementioned factors. It is evident that the Chief of Police has made significant progress in negotiating more appropriate risk mitigation strategies in consultation with local residents. However, it is also obvious that in order to open up channels of communication, agencies must go beyond consultation. Residents must have an active role in planning and preparedness and the local rescue teams must be used as an internal resource to help the community resist, absorb, accommodate to and recover from the effects of an eruption.

The regional Chief of Police has begun action to achieve these goals by holding a meeting with residents in Sólheimar (as mentioned by one Álftaver resident). Together with residents, the police devised a more acceptable evacuation plan for their community (K. Þorkelsson, personal communication, 2008). During a Katla emergency, residents in Sólheimar are to evacuate to a local farm on higher ground rather than evacuating to Vík. Also, in response to the results of this survey, the Chief of Police has ensured that all Sólheimar residents possess the evacuation and hazard information sign (K. Þorkelsson, personal communication, 2008).

Jóhannesdóttir and Gísladóttir (2010) suggested that cooperation, understanding and communication between the scientific community, government authorities and residents is essential to ensure public safety. Since then, much work has been done to improve the community's collective capacity to appropriately respond during a future Katla eruption. However, our study suggests that more work is needed.

Limitations

Interviewer bias is predominantly related to unstructured surveys and the impact of using semi-structured or structured questionnaires is considered as relatively minor

(Sjöberg 2000). However, the issue of bias must always be considered and attempts to minimise its impact adopted. While it is possible that the interviewers might have influenced participant responses in some way, all care was taken to avoid this. Avoidance measures included using only one translator throughout the study in order to minimise inconsistencies in communication. Both interviewers had previous experience conducting face-to-face surveys and were therefore able to ensure that questions were asked exactly as intended and that participant responses were translated fully and completely.

This research benefited greatly from personal connections between the interviewers and participants because a bond was already established. Sharing a similar background has a positive effect by facilitating a rich and detailed conversation based on empathy, mutual respect and understanding (Valentine 2005). Initiating, negotiating and maintaining relationships with participants is an essential component of survey research as it helps facilitate access to rich and detailed information (Maxwell 2005). Within this context, a rapport was particularly important when considering the divide between some residents and emergency management officials as identified by Jóhannesdóttir (2005) and Bird et al. (2009).

It must also be noted that the rural/urban community classification is applied here somewhat superficially. This conceptual approach was used with the intention of demonstrating the heterogeneity between the communities in this case study, and the results presented here indicate a clear difference between the rural and urban populations. However, clear dichotomies do not always appear between rural and urban areas and the heterogeneity *within* communities should also be considered (Allen 2006; Davis et al. 2004; Lewis and Kelman 2010; van Aalst et al. 2008). Cannon (2008) argues that in order to understand vulnerability we need to appreciate that while communities might be perceived as harmonious, they can also be places of highly differing opinions, inequality and maliciousness.

Key findings and recommendations

- All rural and most urban residents displayed accurate knowledge of Katla, the warning system and emergency response procedures.
- New urban residents lacked knowledge of Katla, the warning system, emergency response procedures and did not possess the evacuation and hazard information sign.
- Livelihood connections and inherited knowledge influence rural residents' compliance with evacuation orders.
- Rural residents displayed values of personal responsibility, community involvement in emergency response procedures, community cooperation and neighbourliness.

- Rural residents did not perceive the current plan as appropriate and if conditions during an eruption are dire they would personally assess the situation before deciding on a course of action.
- Rural and urban residents had not adopted personal preparedness measures.
- Urban residents trusted information provided by all emergency management agencies and are therefore more likely to accept decisions and communications from the various agencies.
- Rural residents trusted information provided by scientists.

Based on our findings we recommend that emergency management agencies in Iceland and in other international regions:

- Use factors inherent within communities, such as personal responsibility, neighbourliness, community involvement and cooperation, to develop and implement more appropriate volcanic risk mitigation strategies.
- Devise strategies for selected residents to re-enter evacuated communities so they can tend to livestock.
- Encourage residents to first follow all warning and response announcements on the radio, television or internet.
- Engage the community and persuade them to adopt personal preparedness measures such as possessing masks for inhalation, spare air filters for vehicles, defensive tools to protect infrastructure and emergency kit preparation.
- Distribute regionally specific hazard, risk and emergency response information kits to residents who have recently moved into a hazardous region. This might best be achieved in Iceland through a cooperative agreement between the Icelandic Civil Protection Office and the National Registration Office.
- Consult local communities, learn from their knowledge, have respect for the residents, gain their trust and assist them in developing appropriate emergency response strategies for their communities.

POSTSCRIPT: emergency response during the 2010 Eyjafjallajökull eruptions

In response to the increased seismicity of Eyjafjallajökull during 2009 and 2010, the regional Chief of Police and Icelandic Civil Protection Office organised emergency meetings with scientists, local police and rescue teams. Following these emergency management meetings, the regional Chief of Police and Chief Superintendent from Hvolsvöllur held community information meetings with local residents (S. Rúnarsson, personal communication, 2010). The last of these meetings was held the week before the 20 March 2010 eruption began.

Despite the comprehensive monitoring system, the 20 March 2010 eruption was first announced by local farmers who observed “*a fire on top of the mountain*” (S. Rúnarsson, personal communication, 2010). After reporting these sightings directly to the Hvolsvöllur police and emergency services number 112, the Chief of Police, the Icelandic Civil Protection Office and scientists worked collaboratively to implement an emergency response plan (RÚV 2010; Visir 2010). As a result, approximately 600 residents were evacuated with 440 registering at the evacuation centre in Hvolsvöllur. The remaining residents were housed from Heimaland (see Fig. 1) to Vík in five separate centres. Once the eruption was located on the flank of the volcano, and it was seen that there was no risk of jökulhlaup, residents were allowed to return home. The police were reported as saying that this evacuation went very well, mostly because of the exercises in March 2006 (Mbl 2010).

The eruption emergency was reduced to a ‘hazard phase’ on 13 April 2010 (G. Jóhannesdóttir, personal communication, 2010). However, an increase in seismicity under the Eyjafjallajökull icecap was recorded by the Icelandic Meteorological Office during that evening. In the early hours of 14 April 2010, the Icelandic Civil Protection Office and police worked in consultation with scientists to once again execute emergency response plans and evacuate the most at-risk region, directly south of Eyjafjallajökull. This initial phase of the evacuation commenced at 01:02 GMT (local time) and was completed by 03:22. The remaining areas around Eyjafjallajökull were evacuated by 03:58 (ICP 2010). Due to the risk the ongoing hazards presented to residents, some had to remain in their designated evacuation area for many days.

In August 2010, the authors (Bird and Gísladóttir) carried out a follow-up survey with residents in the communities of Vestur-Eyjafjöll, Austur-Eyjafjöll, Sólheimar, Vík and Álftaver. This survey used a mixture of methods including open and semi-structured interviews and self-administered questionnaires. Although it is beyond the scope of this paper to present the results of this survey (the results are currently being critically analysed and will be presented elsewhere), several points from the interviews are noted below because they have direct relevance to the study presented in this paper. These are:

- Unlike other areas around Eyjafjallajökull, some residents in Vestur-Eyjafjöll were given the option of *voluntary* evacuation after the police considered residents’ reasoning for not following the proposed procedure. These issues were discussed by Bird et al. (2009).
- Strategies were devised for some residents to return to their farms to tend livestock during the evacuation. They had to “*sign in and out of the area*” whenever they returned home to feed their livestock.

- Overall, residents were positive about the emergency response in March and April 2010.
- On a further positive note, residents reported following warning and response announcements on the radio and television as soon as they received the eruption warning from the Icelandic Civil Protection Office. However, many residents stated that they did not receive the Icelandic Civil Protection Office message to their landline or via sms.
- Despite communicating important aspects of hazard and risk prior to the eruption, it appears that emergency management agencies were not prepared for the evacuation of residents. Residents reported that the 20 March evacuation was “*a bit chaotic*”. One resident stated: “*It was so confusing that people didn’t know where to evacuate to, and as a consequence, some people just stayed home.*”
- The international media did little to improve residents’ trust in the media during the crisis by portraying Icelanders as helpless victims and sensationalising the eruption. A Vík resident commented: “*The international media were constantly talking about ‘Iceland erupting’ but they never talked about how life was continuing here.*”
- The decision to allow media reporters into evacuated areas when it was mandatory for nearly all residents to evacuate, register and remain at their designated evacuation centre might have reduced residents’ trust in the Icelandic Civil Protection Office and media. A member of the rescue team remarked: “*The media people went into the farms that had been evacuated and they had a broadcast televised live around Iceland and into the evacuation centres. The reporters were standing on farmers properties; in front of their homes... They [the farmers] had been ordered to evacuate their homes and did not have enough time to even lock their front doors!*”

Conclusions

Many of the issues influencing residents’ perceptions and ability to positively respond to emergency information are complex and deeply rooted within their cultural and social setting. These issues include inherited local knowledge, attachment to place, emotional connection to livestock and a sense of community (e.g. neighbourliness and community cohesion).

Firsthand experience and inherited knowledge have contributed to raising residents’ awareness of Katla. This, however, has not transferred into residents adopting personal preparedness measures nor does it ensure that residents will appropriately respond to emergency informa-

tion. Affecting rural residents' proposed behaviour is an emotional connection that binds them to their livelihood and community. While some aspects of community cohesion also influence rural residents' behaviour, overall values of personal responsibility, community cooperation, community participation and neighbourliness will facilitate an appropriate emergency response.

We have demonstrated that while there are some similarities, differences do exist between rural and urban residents' perceptions, preparedness, trust and potential behaviour if faced with an eruption. It is clear that rural residents have a proactive perspective and want to be involved, not only in consultation, but also in the development of mitigation strategies. Furthermore, rural residents exhibited personal responsibility for their own safety during an eruption. It is therefore likely that rural residents will take control of the situation. In comparison, urban residents have a reactive perspective towards risk mitigation. Urban residents trust emergency information and will follow evacuation procedures when issued.

This research shows that to develop effective mitigation strategies, emergency management agencies must consider local knowledge and perceptions in addition to the specific issues affecting communities. In particular, emergency response plans must be developed in consultation and collaboration with communities to ensure applicability. Risk mitigation must be placed within the context of the society it aims to protect and within a framework that incorporates both the social and physical aspects of hazards.

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