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Risk reduction through community-based monitoring: the *vigías* of Tungurahua, Ecuador

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Abstract

Since 2000, a network of volunteers known as *vigías* has been engaged in community-based volcano monitoring, which involves local citizens in the collection of scientific data, around volcán Tungurahua, Ecuador. This paper provides the first detailed description and analysis of this well-established initiative, drawing implications for volcanic risk reduction elsewhere. Based on 32 semi-structured interviews and other qualitative data collected in June and July 2013 with institutional actors and with *vigías* themselves, the paper documents the origins and development of the network, identifies factors that have sustained it, and analyses the ways in which it contributes to disaster risk reduction. Importantly, the case highlights how this community-based network performs multiple functions in reducing volcanic risk. The *vigías* network functions simultaneously as a source of observational data for scientists; as a communication channel for increasing community awareness, understanding of hazard processes and for enhancing preparedness; and as an early warning system for civil protection. Less tangible benefits with nonetheless material consequences include enhanced social capital – through the relationships and capabilities that are fostered – and improved trust between partners. Establishing trust-based relationships between citizens, the *vigías*, scientists and civil protection authorities is one important factor in the effectiveness and resilience of the network. Other factors discussed in the paper that have contributed to the longevity of the network include the motivations of the *vigías*, a clear and regular communication protocol, persistent volcanic activity, the efforts of key individuals, and examples of successful risk reduction attributable to the activities of the network. Lessons that can be learned about the potential of community-based monitoring for disaster risk reduction in other contexts are identified, including what the case tells us about the conditions that can affect the effectiveness of such initiatives and their resilience to changing circumstances.

Keywords: Disaster risk reduction; Community-based monitoring; Citizen science; Tungurahua; Participatory

Introduction

Volcanic eruptions rarely occur in total isolation, with over 600 million people living in areas that could be impacted by volcanic hazards (Auken et al. 2013). Although active volcanoes can pose threats to the populations living around them, fertile soils, equable climates and increasingly the livelihoods afforded through tourism can exert a strong pull (Tobin & Whiteford 2002; Kelman & Mather 2008; Wilson et al. 2012). Coupled with human attachment to place and community (Dibben & Chester 1999), this means that people may have compelling

reasons to live with the risks associated with volcanoes. Minimising these risks therefore depends upon effective communication and collaboration between volcanologists, risk managers and vulnerable communities.

The challenge of living with a volcano becomes particularly complex in the case of high uncertainty regarding the potential magnitude and duration of activity (Fiske 1984), prolonged periods of unrest (Marti et al. 2009) or during long-lived crises. From the perspective of scientists attempting to minimise the likelihood that volcanic activity turns into a human disaster, a joint focus on the physical hazards and the social context of affected communities is required. For example, even where there is understanding of the physical hazard, an inability to effectively disseminate or to receive warnings that promote action can lead to disaster (Voight 1990). On the other hand, efforts by public authorities to inform and educate,

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when not informed by current scientific understanding, can have limited impact (Bowman & White 2012). In other fields, for example communicating climate risk, an interdisciplinary approach has been found to be the most effective in dealing with uncertain risk problems (Pidgeon & Fischhoff 2011; Fischhoff 2013). Thus, by framing the analysis of volcanic risk within the context of disaster risk reduction (DRR), scientists can help to engage communities as partners in the reduction of risk (Barclay et al. 2008). There is, for example, increasing evidence for the potential value of community-based disaster risk management (CBDRM) (UNISDR 2005; Maskrey 2011) and participatory disaster risk assessment (PDRA) (Pelling 2007). The views and knowledge of people at risk can help to shape future mitigation strategies (Cronin, et al. 2004a,b; Holcombe et al. 2011; Maceda et al. 2009) and involving communities can also be a more effective way to manage hazards (Anderson et al. 2010)^a.

Concurrently the practice of enlisting the help of lay volunteers to monitor and record a natural process has become widespread over the last decade, particularly in the fields of ecology and natural resource management; this practice is often referred to as 'citizen science' and has given rise to a burgeoning research literature (Conrad & Hilchey 2010; Gura 2013). Studies in those fields have demonstrated that 'citizen scientists' can both provide good quality data (Tulloch et al. 2013; Parsons et al. 2011) and prompt community management of important biodiversity issues (Lawrence et al. 2006).

In volcanology, the observations of lay people can provide excellent insights into volcanic processes in data-poor settings, as exemplified by the observations recorded by Pliny the Younger during the eruption of Vesuvius in AD79. Lay observations also help scientists to understand the impacts of complex events (Anderson & Flett 1903) and can provide unique information that may have immediate value in mitigation efforts (Loughlin et al. 2002). Such lay observation of volcanic events is typically informal and unsystematic, and as yet has been little studied for the contribution that it can make to disaster risk management. More systematic citizen involvement in volcanology can also be used, however, to collect multiple data points that sample eruptive products or the properties of volcanic fallout or flows, furthering the understanding of physical processes (Bernard 2013; Stevenson et al. 2013). Importantly all of these activities can have the indirect benefit of enhancing communication, understanding and trust between members of the public and the scientists charged with monitoring their volcano. This has been well documented in other scientific fields (Conrad & Hilchey 2010).

Citizens can also participate in volcano observation and monitoring carried out more systematically with the explicit aim of providing data and understanding that

can be applied to reduce community risk, rather than solely for the purpose of scientific research. This type of participatory activity embedded within the community, specifically for the purposes of risk reduction, is referred to here as community-based monitoring (CBM), where 'community-based' describes the focus and 'monitoring' describes the participatory process. This can also be a vehicle for citizens' participation in volcanic risk management. However, involvement in monitoring and data collection does not necessarily give participants direct influence on institutional decision-making. The monitoring data or observations collected in this way can contribute towards more informed decisions by those responsible for making them.

As already noted, the two-way communication established through scientists' continued engagement with volunteers can support the development of citizens' understanding of and trust in scientists. It can also, however, lead to scientists' developing better understanding of the social, economic and cultural influences on individual decision-making in the face of volcanic risk. This development of improved relationships between scientists and various publics can also lead to improvements in risk communication. The greatest benefit to risk communication demonstrably comes from sustained periods of contact that develop a strong mutual understanding (Fischhoff 1995). Sustained community-based monitoring projects can provide a focus for this type of interaction. In addition, networks established for community-based monitoring can provide a framework within which volunteers can participate in other processes, such as risk reduction planning. Despite the potential value of such approaches, however, there has been relatively limited analysis to evaluate whether in practice the types of benefits described above are realised.

This paper describes the network of volunteers, called '*vigías*', engaged in community-based monitoring around Tungurahua volcano, Ecuador. The Spanish word '*vigía*' can be translated as watchman, guard, sentinel or lookout but, as we shall see, the role of these volunteers extends beyond that which the name suggests. The network, initiated in 2000, has grown to include approximately 35 *vigías* at the time of writing. Recruited initially to provide observations as part of an early warning system, the *vigías* have in practice grown to fulfill multiple risk reduction roles; working collaboratively within their communities and with scientists from the volcano observatory. This paper documents this evolution and examines both the factors that contribute towards sustained and successful participation in the network and the role that the network has played in community response to episodes of volcanic activity. The paper analyses for the first time an important means by which scientists and local communities can work together to enable communities at risk to be more resilient under

conditions of uncertainty and changing volcanic activity. It provides evidence for the conditions under which meaningful participation is sustained through periods of both activity and inactivity at a volcano, and for the contributions to disaster risk reduction made by this approach. The paper concludes by reflecting upon the relevance of this initiative for disaster risk reduction in other settings.

Background

Participatory approaches

Participatory approaches to public problems have become commonplace over the last two decades, giving rise to a wide variety of rationales and labels, such as: “*‘engagement’, ‘empowerment’, ‘involvement’, ‘consultation’, ‘deliberation’, ‘dialogue’, ‘partnership’, ‘outreach’, ‘mediation’, ‘consensus building’ and ‘civic (citizen) science’*” (Chilvers 2008). The lack of consensus on participation, although potentially confusing, is not wholly negative, but reflects the large number of applications and rationales for such approaches (Pelling 2007). Not only is there is no single agreed definition or terminology, the field is also contested both by adherents of particular approaches or participatory practices as well as by researchers and others critical of the unacknowledged consequences of this apparently democratic turn.

A variety of ways have been proposed to categorise the diversity of practices, from early attempts to do so based on the degree of citizen empowerment (Arnstein 1969) to more recent frameworks that use procedural, methodological and ideological criteria (Stirling 2005; Pelling 2007). Whatever it is called, public participation can lead to numerous benefits and challenges, with some forms more likely to result in particular outcomes. Participation has been suggested to: (i) be an ethical and empowering approach (Renn et al. 1995), (ii) lead to better research outcomes (Holcombe & Anderson 2010), (iii) develop trust (Fischhoff 1995) and (iv) promote learning (Webler et al. 1995). On the negative side, however, it can: (i) be used as a political tool (Chilvers 2008), (ii) not lead to the empowerment it appears to promise (Cooke & Kothari 2001; Stirling 2005; Pelling 2007), (iii) consequently lead to distrust (Wynne 2006) and (iv) be nebulous and frustrating for the participants (Bowman & White 2012).

The involvement of communities has been firmly on the disaster risk reduction (DRR) agenda since Hyogo, 2005 (UNISDR, 2005). Within the field of disaster risk reduction, participatory initiatives can include community-based disaster risk management (CBDRM) (Maskrey 2011), community-based monitoring (CBM) (Holcombe & Anderson 2010) and community-based early warning systems (CBEWS) (Garcia & Fearnley 2012; Bowman & White 2012) and many have advocated participatory approaches to managing volcanic risks (Barclay et al. 2008). It is therefore important to collect evidence about the efficacy of the approaches adopted.

Participatory approaches and trust

As well as the direct benefits from additional data, ongoing participatory monitoring provides an indirect benefit via the changing dynamics of trust between scientists and participants that could take place. Trust can have many dimensions, including: *perceived competence, care, fairness, openness, value similarity, credibility, reliability and integrity* (Poortinga and Pidgeon 2003; Frewer et al. 1996; Renn & Levine 1991). Interactions between scientists and participants allow them to learn that they often have shared values, and that both groups are competent and open. This process is important both-ways; scientists also need to learn to trust participants who are sending them information. Trust not only affects the risk communication process (Haynes et al. 2008; Paton 2007), but allows for decisions to be made despite risk (Luhmann 2000). Whilst trust is considered to be asymmetric, needing a long time to be built, but eroded quickly (Slovic 1993), trust within strong relationships tends to be more resilient to changes or shocks (Earle 2010), such as those associated with enduring periods of volcanic uncertainty or high impact volcanic activity.

Tungurahua

The research is focused around Tungurahua, an active volcano in the Ecuadorian Andes (Hall et al. 2008). Prior to the 1999-ongoing phase, historical eruptions have occurred in 1640, 1773, 1886 and 1916–1918 (Hall et al. 1999). Since 1999, the eruptive activity has varied between violent Strombolian to Vulcanian style explosions with associated pyroclastic flows, lava jetting and weaker explosions with ash emissions (Le Pennec et al. 2011; Fee et al. 2010; Ruiz et al. 2005). Pyroclastic flows are of particular concern to communities on the volcano’s western and northern flanks, including the large town of Baños (Hall et al. 1999). Tephra fall has and continues to have impacts on communities in the region, including Baños and nearby cities (Le Pennec et al. 2011) (Tobin & Whiteford 2002), and lahars pose a persistent hazard even during periods of quiescence (Williams et al. 2008).

1999 evacuation of Baños and surrounding faldas

Eruptive activity at Tungurahua resumed in October 1999, following 80 years of quiescence and several years of unrest. Initial activity was phreatic, then magmatic as of the 11th October 1999 (Le Pennec et al. 2011). An evacuation of the town of Baños and surrounding communities (*faldas*) was called by the President of Ecuador on 16th October (Tobin & Whiteford 2002). Activity increased to include violent Strombolian and small Vulcanian explosions from the 28th October, with the first eruptive phase lasting until 10th December 1999 (Le Pennec et al. 2011). Many people from Baños worked in the tourism industry, and those from surrounding communities in agriculture.

The evacuation was enforced by the army and led to the loss of access to livelihoods and a growing feeling of desperation (Lane et al. 2003; Tobin & Whiteford 2002). Members of the community formed a group known as *Los Ojos del Volcán* (Eyes of the Volcano), observing the volcano and Baños from a nearby safe hilltop location. Evacuees, distrustful of official scientific information, turned to the group as an alternative source of information. They were effectively a self-appointed voice of the displaced population. Despite a resumption of activity in late December 1999 (Le Pennec et al. 2011), some residents of Baños forcibly re-occupied the town on 6th January 2000, overrunning army checkpoints. This led to others re-occupying the abandoned *faldas*, despite fluctuating volcanic activity throughout 2000. Re-occupation, even in the face of official efforts to maintain an evacuation, is not unique to Tungurahua, but suggestions are that it often occurs at other volcanoes worldwide (Bohra-Mishra et al. 2014). Following the re-occupation, *Los ojos del volcán* effectively disbanded.

At the time of the interviews (June & July 2013) the volcano was in a cycle of Vulcanian explosions and heightened activity for a few weeks approximately every three months. Tungurahua is monitored from the Tungurahua Volcano Observatory (OVT) (Figure 1) by the Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador (IGEPN).

Methods

To explore which factors may contribute towards sustained participation and risk reduction around Tungurahua, qualitative methods, including both semi-structured interviews and less formal ethnographic methods, were chosen for this research because they yield a contextualised understanding of the motivations of, and interactions between, the different actors (in this case *vigías*, scientists, authorities, other citizens) and the natural environment.

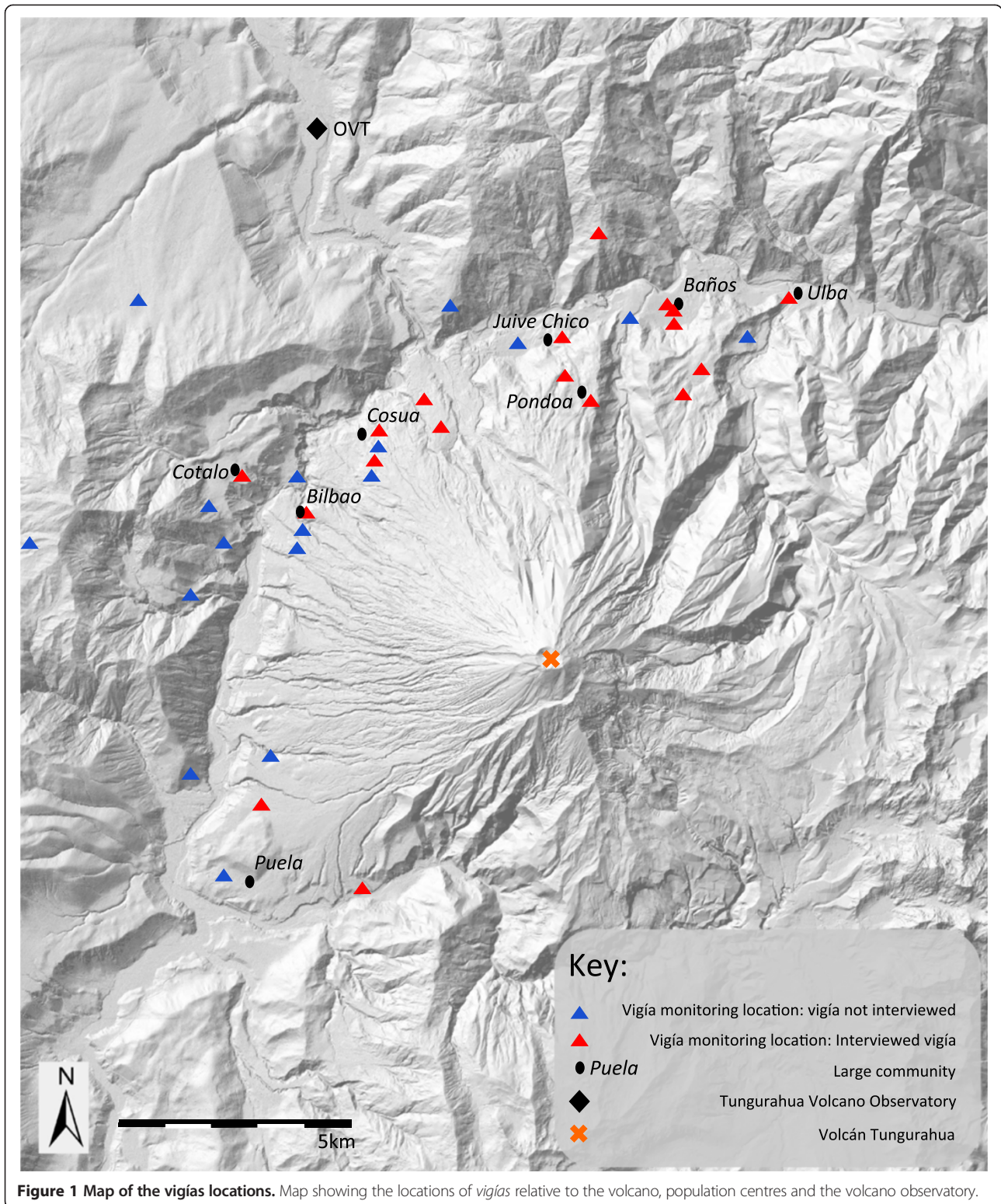
The research proposal underwent institutional ethical review and was conducted according to UK Economic and Social Research Council ethical guidelines (ESRC 2012). The approach taken to recruiting interviewees to the study was different for each of the groups contacted. All *vigías* were approached for interview, either through the *vigía* network or through direct approach by a local field assistant, but some were unavailable. Of the approximately 25 *vigías* who participate regularly in the network, 19 were interviewed. Other members of affected communities who were interviewed were recruited using a snowball sampling approach (Bryman 2004). *Defensa Civil de Ecuador* (Civil Defence) and municipal officials were contacted through IGEPN. Research participants were asked to give consent to audio recording of the interview, told that their quotes would be presented anonymously in any publications and given the contact details of the author should they wish to withdraw from the study at a later

date. The researcher was presented to the *vigías* and other citizens as a scientist from the UK wanting to investigate how the system of risk management around Tungurahua functioned; the local field assistant, rather than a member of IGEPN staff, acted as interpreter in order to minimise any effect that identifying the researcher as a scientist might have had on interviewees' responses. Similarly, efforts were made to avoid the potential for bias if only the most active or enthusiastic *vigías* were interviewed by also interviewing two 'inactive' *vigías*.

The semi-structured interviews were guided by an initial list of questions to focus the discussion (Additional file 1). Interviews with *vigías* and local citizens were carried out with an interpreter, although the author made use of conversationally proficient Spanish to probe responses. All interviews were recorded, transcribed, and then translated where necessary into English. Semi-structured interviews facilitate a more flexible approach to data collection, allowing the interviewee to frame their answers in their own terms and, where appropriate, to connect them to wider issues, which in turn allows the researcher to gain a deeper understanding of how those issues are understood from the respondents' point of view (Arksey and Knight 1999).

In addition to the semi-structured interviews, data were also collected using more informal ethnographic methods. The first of these, participant observation, is a technique where interactions in professional and everyday contexts of the social groups that are the focus of the research are observed and noted by the researcher. This is a non-intrusive form of data collection and particularly important as it gives contextual insight into ways of being and relationships between the actors. The first author was present at numerous meetings, informal conversations and chance encounters between different actors, and observations made at these times gave context to the themes and topics identified from the interviews. In addition to collecting observational data in these different settings, 'conversations with a purpose' (Burgess 1984) allowed for impromptu data gathering when a formal interview was not possible. The researcher was able to gather data during informal conversations with the *vigías* and with other local people, as well as with officials and scientists, by asking short questions related to the research. Although the conversations were informal, it was possible to verify the quality of the data by 'triangulation' between different data sources (Denzin 1970), where the same accounts or issues emerged from interviews, participant observation and conversations with a purpose, thereby increasing the reliability of the interpretations that were made.

Once they had been transcribed and translated, the data were subject to thematic analysis using a coding-based approach (Bernard & Ryan 2009). Codes are shorthand labels that can be applied to units of meaning in the data that



may have analytical significance. Initial codes used were derived from theory-related material in the literature on participation in DRR; including aspects relating to successes and limitations, and to the dynamics of trust in

relationships between the various actors. The coding was performed manually on translated transcripts, but with frequent reference back to the original Spanish transcripts. An iterative approach was taken, with systematic re-

reading of transcripts and notes leading to the application of additional codes derived inductively from the data (Strauss & Corbin 1990). From this process, several themes emerged: initiation of the network/recruitment, motivations of *vigías*, network organisation, key individuals, risk reduction examples, relationships, risk communication, and challenges and applicability of the network elsewhere. Each of the themes were then associated with verbatim quotes. The results of the thematic analysis are then presented here and exemplified by verbatim quotes of representative responses from the interviewees. This, combined with the contextual information from participant observations and conversations with a purpose, gives deeper meaning and validity to the results.

Origins and development of the *vigía* network

Initiation of the network

The network of volunteer *vigías* around the volcano began in late 2000, as part of an initiative from several stakeholders, both from those within the established risk management structure and the communities themselves. Civil Defence (at the time responsible for disaster management) needed to be able to communicate early warnings to communities in order to prompt timely evacuations:

“So what happened was that after the evacuation of Tungurahua, once people had finally fought their way back, it was considered that there had to be a feeling of self-empowerment and there had to be a more integral form of communication. It came out of the idea of Colonel Rodriguez from the Civil Defence. He had some funding and he thought the best thing, being a military man, is that you need to have better communications; because there was absolutely no way that we could get information out to anyone living near the volcano. I wasn't really involved in all of these discussions, although he (Col Rodriguez) and Javier Jaramillo (Civil Defence volunteer and fireman) did talk to me about it and I probably said it was a great idea. But I did go with Javier Jaramillo on several occasions and we found particular people”. (Scientist 1)

Concurrently, the scientists wanted to have more visual observations to compliment their monitoring network:

“Since we could observe only the North and West flanks of the volcano from the OVT, we felt that we needed the help from local observers on the other flanks of the volcano”. (Scientist 2)

From the perspective of the *vigías*, they and their communities wanted information, and they wanted to have and be part of, some form of early warning system to enable them to live there with less risk. Initially the *vigías*

maintained and managed sirens in communities on the volcano. The demand for such a network, from several stakeholders at once, which fulfilled multiple roles, contributed towards its success initially. The *vigía* network was a pragmatic solution to a real risk problem.

Vigías were recruited as Civil Defence volunteers; the first were recruited due to already being part of the Civil Defence and others were known to scientists as a result of monitoring equipment located on their farmland. Other *vigías* were recommended by each other, and the scientists along with Civil Defence commanders, visited locations to identify yet more *vigías*:

“They went around identifying people who would be, first of all in strategic areas with good sight of the volcano to be able to tell you something, if the volcano was clear - or hear it. Secondly, people who were possibly good communicators – you don't know that at the time, but you had to take a bet. And third, was that they seemed like the kind of people who would want to be involved in this kind of thing, they were sociable and friendly”. (Scientist 1)

Many of the *vigías* work in agriculture, but others are teachers, business owners and municipal employees (Table 1). None of the *vigías* were formerly members of

Table 1 Demographics of the *vigía* interview respondents

Characteristic	Count
Gender	
Male	16
Female	3
Occupation	
Agriculture	15
Municipality	2
Education	1
Business owners	1
Drivers	1
Length of time as <i>vigía</i>	
10 - 14 years	13
5 - 9 years	5
0 - 4 years	2
Primary recruitment path	
Existing Civil Defence volunteer	5
Head of community	5
Municipality nominated	2
Through another <i>vigía</i>	1
National Secretariat for Risk Management (SNGR)	2
Scientists	4

Los Ojos del Volcán, which disbanded soon after the re-occupation in 2000.

From the outset, the *vigías* had two roles; to facilitate evacuations as part of the Civil Defence communication network embedded in communities, including the management of sirens, and to communicate observations about the volcano to the scientists. A fireman, who was also a Civil Defence volunteer, helped to upgrade their local VHF radio network, enabling radio communications around the flanks of the volcano with repeaters to the town of Baños and OVT, and the *vigías* were given handheld radios:

“You know, it evolved, people just showed up, like Javier just showed up and said “I’m going to put in this base radio and now all these vigías have these radios and are going to start talking”. And they had to put in the repeater up there on the hill. And all of this happened, we really didn’t have to lift a finger apart from to say, this is great, let’s do it”. (Scientist 1)

The *vigías* were given basic training from the scientists about what to observe, how to describe phenomena and how to communicate with OVT. Every night at 8 pm, someone from Civil Defence would call on the joint (OVT, Civil Defence) radio system and ask the *vigías* to report in. If activity changed then communication frequency would increase. If a *vigía* missed several radio checks they were told to participate properly or not be part of the team. As a senior scientist describes it:

“The people were badgered, if they wanted to be part of the system then you’re going to have to step up to the plate and talk. That went on for years”.

Clearly defined roles, responsibilities and communication protocols, aided by Civil Defence commanders’ military backgrounds, ensured the efficacy of the network and helped to stop the spread of competing information about the volcano. Key individuals from IGEPN and Civil Defence have had a considerable impact on the success of the network, from initiating it, installing the VHF system, recruiting and training *vigías*, and in developing procedures to maintain relationships.

Expansion of roles

As time progressed the roles of some *vigías* diversified, to include maintenance of the IGEPN monitoring stations around the volcano, clearing vegetation and ash. This responsibility came with some payment from IGEPN. Other *vigías*, who lived near the volcano’s major valleys were given motorbikes by Civil Defence so that they could check for lahars during rainfall, which is very important for the protection of the town of Baños and the Baños – Ambato road. Further initiatives included the installation

of ashmeters at locations including the *vigías*’ properties, which they maintained, to assist with the measurement of ashfall around the volcano (Bernard 2013).

Motivations of the *vigías* in the early network

The motivations for the *vigías*’ initial and continued involvement are an important component of the network’s success. All *vigías* in interviews stated that they felt a sense of duty or moral obligation and that they wanted to help reduce risk to their family and community. *Vigías* repeatedly stated that the voluntary nature of the role is very important to them. Other motivations included those that come from risk reduction success and some financial incentives for maintenance roles, available to those who lived or worked near to monitoring stations. The social identity of being a *vigía* is also important; most *vigías* wore at least their Civil Defence cap during meetings, and working in this official capacity was a source of pride. Some informants suggested that being a *vigía* led to them being elected as leaders and representatives of their communities.

Interviewees repeatedly commented that the continued volcanic activity, which has posed a threat to the communities since 1999, gave the network a strong sense of purpose (Le Pennec et al. 2011).

Evolution of the network

Shortly after the network was formed, there were approximately ten *vigías*. This number grew gradually with time to approximately 20 before August 2006 (Table 1). There was a rapid expansion in numbers of *vigías* after the August 2006 eruption, with some sources suggesting that the number increased to over fifty for a short time. This was a pivotal event, in which lives saved in the Juive Grande area were attributed to the presence of *vigías* working with OVT, and lives lost in Palitahua were thought by the majority of interviewees who discussed it to be in part due to difficulties communicating with people living there, perhaps due to a lack of *vigías* in that location.

In 2008 Civil Defence was disbanded and reformed as SNGR (National Secretariat for Risk Management). The head of Civil Defence in the Baños area was not given the equivalent role in SNGR. Many *vigías* commented during interviews that they did not know the new director, and felt that SNGR did not prioritise supporting the network in the same as way its predecessor, citing a perceived reduction in resources as evidence of this. This may be as a result of fundamental differences in the remit of SNGR and the risk management strategies that it consequently employs, when compared to the Civil Defence organisation that it replaced, particularly the decentralised management system where any funding for DRR would have to come from a municipal SNGR budget. These factors have led to the *vigías* becoming semi-autonomous

and working primarily with the scientists. The current resourcing of the network does not reflect the pivotal roles played by these volunteers in risk reduction activities, as displayed during eruption crises in July and October, 2013 and on 01 February, 2014 (IGEPN 2014). According to scientists and responding agencies - their actions contributed to the zero loss of lives or injuries during all of these eruptive events.

Network in 2014

The network at the time of fieldwork had approximately 35 *vigías*, of which about 25 are currently active and have working radios, communicating with OVT each evening at 8 pm. The number of 'inactive' *vigías* is hard to determine. The inactive *vigías* may not participate regularly due to a number of factors including: a lack of working radios, multiple *vigías* in one location, a lack of time or enthusiasm. However, despite not actively participating in the network daily, many of the inactive *vigías* were said by other *vigías* to fulfill some role during evacuations. The communication network is maintained technically (radio maintenance, calibration and installation) by the chief of the Patate town fire service on a voluntary basis. Administration involving talking to the *vigías* at 8 pm daily and chasing any non-contributors is carried out by one of the *vigías* located in Baños. The *vigías* of Tungurahua province now feel as if they are not part of SNGR. In effect, they are their own network, with limited resource input from the authorities. Although the whole network functions as one, the *vigías* located on the portion of Tungurahua in of Chimborazo province are a little more integrated with SNGR, a fact that is apparent by their possession of newer uniforms and radios. Some separate arrangements are made between IGEPN and those *vigías* near to monitoring stations who perform a maintenance role. The *vigías* are seen as an important part of the volcano management system by people within the communities on the flanks and in the main town of Baños. In late 2013 the SNGR gave *vigías* new radios and batteries and also a modest donation was given by the US Embassy in Quito, to help support the overall radio system and provide a set of field gear to all *vigías*.

According to interviewees, the network has benefitted from regular field visits of scientists from OVT, spending time with *vigías* and members of the community, and inviting them to meetings and workshops. At the time of interview all *vigías* stated that they primarily work with the scientists (OVT), but it is likely that before the change from Civil Defence to SNGR, there was a stronger association with civil protection.

There is a sense, from scientists at the OVT, that the eruptions are becoming more dangerous because they have recently been forming pyroclastic flows, which threaten the

villages and grazing lands around the volcano's base. The *vigías* have a vested interest to maintain their attention level and contribute to the vitality of the communication system in order to be ready for the next eruptive event.

Outcomes, challenges and implications for disaster risk reduction

Previous sections have described the network, from initiation and evolution through to the present. This section will discuss the outcomes and challenges as a result of this initiative, and the relevance of this type of network away from the specific case context of Tungurahua. These topics will be discussed by drawing on some of the themes identified by the analysis of the data: relationships, trust and risk communication; risk reduction; threats to the network and implications for practice in other volcanic areas. The effect that the sustained hazard at Tungurahua has had on the network crosscuts many of the topics discussed in this section.

Relationships, trust and risk communication

The network has evolved over time from being a civil protection CBEWS, to having a stronger association with volcano monitoring and the communication of risk information, coinciding with or as a result of changing relationships with the institutions that interact with the network. Much of the successful and sustained involvement in this network can be attributed to the strong relationships between stakeholders. Relationships between the *vigías* and scientists are based upon regular communication; regular visits by scientists to the communities and shared motivations, values and priorities. This is consistent with suggested factors for success in CBM (Conrad & Hilchey 2010). In interviews, the *vigías* talked of the scientists as friends and colleagues, describing an equal standing. When observing the interactions between scientists and the *vigías*, it is striking how much time each spend with the other, talking about all manner of things, regardless of the time of day. In short, the scientists were never too busy to stop and talk to not just *vigías*, but other members of the community. The scientists often bring some gifts, normally food, and receive refreshment in the homes of the *vigías*. It was evident from the interviews and participant observation, that the ways in which the scientists treat the *vigías* and vice versa, has a big impact on the success of the network. Similarly, relationships developed between the *vigías*, as a result of regular communication, meetings organised by IGEPN and a strong sense of community. Finally, the *vigías* act as a bridge between the community and the scientists. Thus this participatory communication pathway from scientists to *vigías*, and *vigías* to their friends and family (community), results in an efficient and effective way to communicate risk information (Fischhoff 1995; Barclay et al. 2008),

consistent with similar participatory initiatives elsewhere. In some cases, the public distrusts the motivations of scientists when they give advice to authorities, perceiving that advice will adversely affect their interests. The unique position of the *vigías*, as members of the community, allows them to act as intermediaries between the scientists and public, benefitting from dimensions of trust such as value similarity and credibility. Whilst this doesn't necessarily mean that citizens explicitly trust the scientists, their confidence in the *vigías* suggests that they are more likely to respond to scientific advice:

Interviewer: *"Has the opinion of the public towards the scientists and authorities changed at all due to the vigías?"*

Resident of Baños: *"Quite a bit, because the vigías are people like us".*

Interviewer: *"It's very important?"*

Resident of Baños: *"Yes, because as the scientists are somewhat higher than us, and they think that they know more than this, but the vigías are people like us and feel too. The scientists only go to talk, not with feelings, like the vigías".*

Interviewer: *"Do you have more confidence in the scientists, because the vigías are in the communities?"*

Resident of Baños: *"More confidence in the vigías because it is they who are living in the community with us, they know the behaviour of the volcano".*

Communication to the community can often be directed through the network, where, without 'translation', many *vigías* put their handheld radio in the center of a room to allow friends and family to hear what is happening, or in some cases through a loudhailer (megaphone) so that members of the community can hear what other *vigías* and the scientists are saying. Although this is contrary to the desired communication protocol (Figure 2), scientists stated that this is an important communication pathway, as often the official protocol from *scientists - authorities - communities* breaks down at the 'authorities' stage or is too slow for timely risk reducing actions to be taken. This informal communication pathway is not without its potential problems but criticisms were not voiced by any of the stakeholders interviewed.

Trust-based relationships are very important in the development of the network, interactions between stakeholders, for the process of risk communication and in developing the network's adaptive capacity. In many

cases, the relationships between scientists and the *vigías*, and the dimensions of trust upon which they are built, were built and maintained by the same key individuals who initiated the network. This leadership behaviour became a model that was adopted by other scientists and thus became institutionalised within IGEPN. Even volunteer observatory staff acted in this way and in turn were respected by the communities. A *vigía* describes how his relationship with the scientists has changed over time:

"At the start, I only knew them through telephone calls, through the radio, but then more so in the meetings and training events. We have become better friends through the reunions because they are people who we can talk to and this shows a growth in trust and we now know what they think, what they do, not only talking about the eruptive process but also about our lives and how we live. Sometimes we can have a laugh based on the trust we have gained".

Another *vigía* describes how the trust in the relationship develops with time:

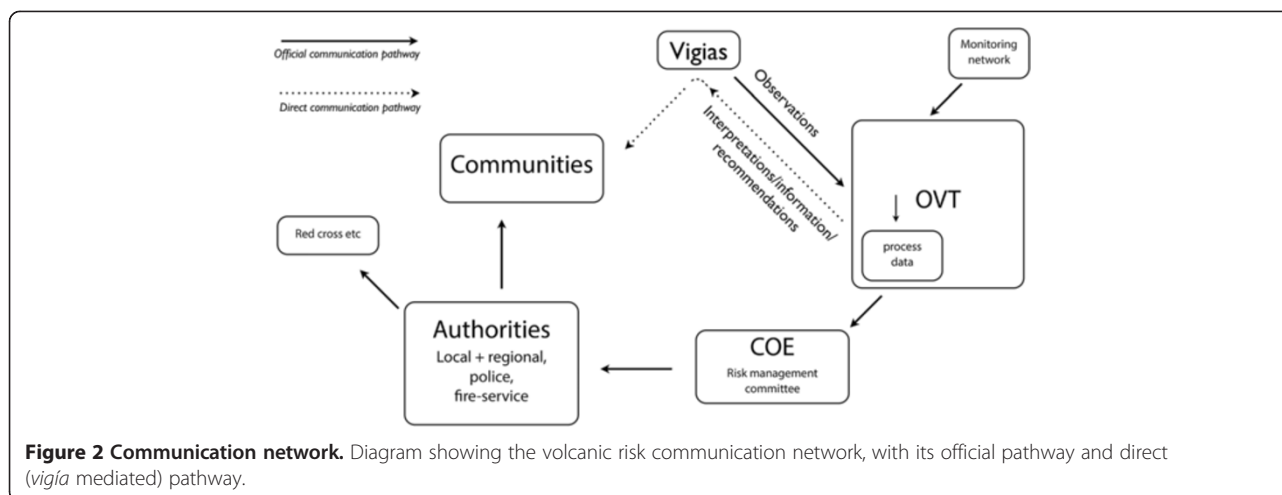
Interviewer: *"How much time do you believe is necessary to strengthen the relationship between the community and vigías?"*

Vigía: "It's a long process, we have to see results and when there are results, people gain trust".

The network has also helped to address the public mistrust of scientists and authorities following the 1999 evacuation, as described by a *vigía* from Baños:

"Initially, the relationship between the OVT and the town was bad, for sure, by certain leaders, a gap was formed. But when we returned, the early alert system was formed with the vigías, with sirens, that was what united the OVT with the officials and the town. The vigías were the link between the authorities, the town and the observatory, so it wasn't just the scientists and the authorities, there were people from the town working for the community. At the start, when there was no radio communications, we spoke person to person and sometimes the information changed, now there is quite a positive trust from the town towards the scientists".

Relationships are extremely important, allowing people to act with confidence and with certain expectations, meaning that those within the network will often make efforts beyond their expected duties, allowing it to have the capacity to respond and adapt to changes. By developing the characteristics of social capital, i.e. reciprocity, which are then beneficial to the community, the network



is able to help the community develop in other ways, that are not explicitly DRR.

In uncertain situations with changeable activity, the strong bond of trust between the *vigías* and scientists allows for the propagation of scientific information and advice more directly to the communities at risk, especially under conditions of citizen mistrust. This relationship between the scientists and *vigías* encourages people within the communities to take risk-reducing actions that are more guided by scientific information. Hence when people receive recommendation for an evacuation from a trusted source, either unofficially through the direct communication pathway or via the official mechanism, they tend to make a quick decision (Luhmann 2000). Trust has also been shown to be vital in the communication and uptake of risk information (Haynes et al. 2008; Paton et al. 2008; Garcia & Fearnley 2012). In its current state, with a lack of direction from SNGR, the network is sustained by the relationships between the *vigías*, scientists and key individuals in the fire service. Trust engendered through these relationships can contribute towards the network's success. This success in turn helps to further develop trust and to sustain the network.

Risk reduction

The overall objective of the *vigía* network is to reduce risk to communities surrounding Tungurahua. It was initiated out of a compromise between citizens - who had forcibly returned to hazardous localities following an enforced evacuation - and the civil protection agencies attempting to ensure their safety. This pattern of evacuation and return, even against official advice, is a familiar one in volcanic areas, as well as in other settings (Bohra-Mishra et al. 2014). The network is therefore an adaptive compromise, requiring the cooperation of all stakeholders,

which has enabled citizens to continue to live and work in hazardous areas by enhancing their capacity to respond quickly to escalating threats. The chief of the fire service for the region encapsulates the perceptions of its achievements: "If we didn't have these *vigías*, there would have been many deaths".

A corroborating example of this is during the August 2006 eruption where *vigía* observations of the beginnings of pyroclastic flows in the Juive Grande *quebrada* (valley) led to a speedy and successful evacuation of many people, facilitated by the *vigías* themselves. Lots of property and land was lost, but no lives in that location. In the weeks and months following this activity, the *vigías* systematically alerted authorities to lahars in that area, which would regularly cut the main road from Baños to Ambato. The *vigías*, many of whom were or have become community leaders, are able to make a transition between volunteer observer and community-level decision maker in times of crisis, and by communicating with each other using the network, communities can coordinate evacuations. The clear communication protocol of the network, requiring *vigías* to connect with each other, the scientists and authorities by radio at the same time every evening regardless of the level of activity, means that involvement is sustained during periods of quiescence at the volcano, continuing the development of relationships, thus preparing the network to respond to future crises.

In addition to the benefits of direct communication and monitoring, many of the *vigías* have a vital role in maintaining monitoring stations around the large volcano, without which the scientists' capabilities would be severely reduced. The upkeep of these stations has a secondary effect, in that when volcanic activity is low and thus there isn't much to report, the *vigías* still have an active and important role. During times of heightened activity at the

volcano, their observations are deemed important by the scientists, as they confirm instrumental observations and are less affected by technical problems, as described by a *vigía*:

"Instruments aren't always reliable, so as perfect as a machine could be, it could fail, therefore, what I believe, is that it is very important to have the commentaries given by the vigías".

Another benefit of the network is that the *vigías* are embedded members of the community and their involvement has led directly to greater involvement in risk reduction planning with a focus on preparedness, involving a network of civil society that is much wider than just the *vigías*. This allows the community to access resources and support in order to develop evacuation plans, protect resources such as water and assist groups such as the elderly or disabled. The data collected by the network has also led to scientific publications (Bernard 2013). Apart from reducing volcanic risk, the network has been able to coordinate the response to fires, road traffic accidents, medical emergencies, thefts and assaults, and to plan for future earthquakes and landslides.

The risk reducing effects of the initiative are further described by the 'self evacuations' that frequently occur. In these situations, *vigías* and community leaders initiate evacuations in response to sudden increases in activity. These instances are partly as a result of the direct communication pathway (Figure 2) and also due to the inevitable lag-time before official mechanisms are able to work. Although pre-emptive evacuations would further reduce the risk, citizens have demonstrated the desire to stay in their homes for as long as possible. What the self-evacuations demonstrate is a sense of agency and capacity possessed by the communities, where they are able to preempt official decisions and thus more quickly respond to changes in the level of risk.

Threats to network stability and effectiveness

The functioning of the network is dependent in many ways on contextual factors, some of which have been subject to change, with a number of past, present and potential future threats uncovered during the interviews and the analysis. The network relies on the support afforded by influential scientists, charismatic *vigías* and emergency management officials, who established and/or who continue to champion the network. The effect of losing key individuals, who have been instrumental in this, is therefore an important consideration. We can see this following the reorganisation of risk management in Ecuador; the officials occupying key posts in the national or regional risk management institutions that have replaced the Civil Defence have different priorities, which

may, either by providing inadequate resource or by having reservations about making the *vigías* part of their institution, limit the effectiveness of the *vigía* network. This lack of institutional identity, where the *vigías* used to be firmly part of Civil Defence, but now are just associated with SNGR, is an issue. The idea that the *vigías* are adopted as part of OVT was discussed, but this poses a challenge for OVT - if the *vigías* became part of their institution, among other things it could change the dynamic of *vigías* being intermediaries between scientists and the communities. Another challenge is the current lack of resources, from essential batteries for the radios to the symbolism of not replacing fading uniforms. This threatens the institutional identity or sense of worth that can be so important to the *vigías* motivations. This creates pressure from outside the network, where some people, such as family members or people in the community, question why the *vigías* work so much for free, with some suggesting that the authorities are taking advantage of them, or even seeming to have the suspicion that they are in fact paid.

One important question that might be asked is what role the *vigía* network might play in the event of an eruption of greater magnitude than those that have occurred during the 1999-ongoing phase of activity, but which the historical record shows to have occurred regularly in the past (Hall et al. 1999). On the one hand, the now well-established communication pathways, together with the heightened levels of preparedness and trust in scientific advice might be expected to enable communities to act to reduce the risk in a timely manner. On the other hand, however, in view of what has already been said about the circumstances from which the network emerged, one might ask whether the very presence of the *vigías*, although there to reduce risk, might actually encourage more people to live close to the volcano because of the increased confidence that they and the network inspire. A senior scientist responded to this point:

"They'd be there anyway. They feel a little safer but most of them would be there anyway, but perhaps they might stay on a little bit longer than they should. Basically there is a lot more choice in this situation than elsewhere. I want [the vigía] to be able to run his cows up there on the hill and those guys to get the bumper crops of corn if they can and provide the education for the kids and think 'this is my life and I'm producing it'."

When it is considered that the network was formed as a pragmatic solution to people deciding to forcibly return to their homes and livelihoods, its benefits outweigh potential negative effects. Despite the threats and

challenges, this CBM network has empowered people to take ownership of problems, consistent with findings elsewhere (Lawrence et al. 2006), and has proved to be a successful way to manage and mitigate a hazard, as has been shown elsewhere, e.g. Anderson et al. (2010).

Implications for other volcanic settings

A significant aspect of the success of the network must be attributed to the behaviour of the volcano itself. It is an obvious but important point, that without volcanic activity initially, the network would not have started. Equally important is that without regular periods of heightened activity threatening communities or their ways of life, it would not have continued in its current form. This was identified as an important factor by most *vigías*, scientists and members of the authorities when asked about the potential for similar networks elsewhere. The potential hazard from the volcano, although fluctuating, keeps them focused on participating in such a network to reduce the risk to themselves and their communities. It is perhaps with infrequent or very limited activity that a network similar to this, which jointly fulfills citizen science and CBEWS roles, would be difficult to replicate elsewhere.

In the absence of persistent volcanic activity, other forms of participation which are not necessarily monitoring volcanic activity, but embedded within public engagement initiatives by observatories, could lay the foundations for participation in a future network able to respond dynamically to increased risk. Thus participatory activities such as PRA (Cronin et al. 2004b) or participatory mapping (Maceda et al. 2009), can act to build capacity, laying the foundation for building future CBM networks if required, even though other forms of participation may not necessarily enhance relationships and trust in quite the same way as long term monitoring does.

To replicate the network elsewhere, many respondents suggested that working in a voluntary capacity was very important, along with a strong desire from all stakeholders. However, for participation that goes beyond observations and enhancing community preparedness, i.e. that which involves equipment maintenance or other activities that directly benefits the work of the scientists, then payment is necessary and important.

It is important to think carefully before applying participatory approaches in DRR settings, to ensure that realistic outcomes are defined and considerable attempts are made to foster equitable relationships between stakeholders. Whilst empowerment through participation is ethically a good outcome, it should be built by consensus rather than conflict and is largely dependent on the cultural and political context (Stirling 2005). Indeed, community empowerment and a shift from a top-down technocratic approach to a bottom up approach is not necessarily the most effective way to achieve DRR; the most effective

approaches should maximise a combination of scientific, community and local expertise, integrated into national and regional DRR policies (Pelling 2007; Maskrey 2011).

Evidence presented in this paper suggests that strong relationships, with all of the risk reduction benefits stated above, can be built through interactions between scientists and citizens, contributing to sustained monitoring, improved risk communication and community involvement in DRR at a local level.

Conclusions

In volcanically threatened areas, where hazards are often persistent regardless of volcanic activity, community-based monitoring has the potential to reduce risk by providing useful data, fostering collaboration between scientists and communities, and providing a way in which citizens are empowered to take actions to preserve lives and livelihoods. The *vigía* network around Tungurahua provides collaborative risk reduction that has had substantial effects for more than fourteen years. The network was formed in response to a need to improve the communication of risk and the coordination of evacuations for communities around the volcano. Of particular relevance is that it was initiated as a compromise following citizens' decisions to forcibly return to hazardous areas following an enforced evacuation. This pattern of reoccupation following a period of heightened activity is common in other volcanic settings. The network provides a pragmatic solution to the situation created by the reoccupation of hazardous areas, by enhancing community capacity for taking protective action, as demonstrated by the auto-evacuations, thus enabling risk reduction. The research shows that the network benefitted from key individuals who pushed the idea forward, and grew as a result of a demand from communities, scientists and authorities simultaneously. It is characterised by how information is shared across the network between *vigías*, between *vigías* and community members, and between the *vigías* and scientists.

By having clearly defined communication protocols and training, the network has performed efficiently, minimising instances of incorrect information being distributed. The regular, at least daily, communication has meant that the communities have remained focused on risk reduction. This and frequent face-to-face interactions with scientists, who act in a friendly and approachable manner, has fostered interpersonal trust between scientists and *vigías*. These strong relationships have also engendered citizens' confidence in the system of *vigías*, scientist and authorities, resulting in prompt evacuations at times of high risk, and an increase in the uptake of risk information. The *vigías* have been able to greatly assist the scientists by maintaining monitoring stations, and providing vital visual observations of volcanic activity. The voluntary aspect of the *vigías'* work is important, with their motivations

including a sense of duty or moral obligation to help their communities. The relationships between *vigías* and scientists have made the network resilient to changes, such as periods of inactivity and the restructuring of civil protection that has affected the resources available. There are, however, threats to the network, including a loss of institutional identity and a reduction in the resources provided to support its activities as a result of changes in risk management institutions. The future of the *vigía* system depends to some extent upon the persistence of eruptive activity. If the eruptive threat ceases, the motives to sustain the communications system and the close personal contacts between *vigías* and scientists would require a change in focus. *Vigías* have a strong sense that they are vital players in the early warning system and that they are also among the first individuals to know, from the signals given from the volcano and from their interaction with the IGEPN scientists, when the next eruption might present itself. They, like the monitoring scientists, want to make an appropriate assessment of accelerating pre-eruption activity.

This paper shows that community-based monitoring can directly contribute to risk reduction around volcanoes and other forms of extensive hazard, in a number of ways, by contributing observations of on-going phenomena and their evolution, enhancing risk communication, facilitating community preparedness and mediating relationships between scientists and the general public. It demonstrates the enhanced capacity fostered by strong trust-based relationships built by sustained contact between the public and scientists, allowing communities to adaptively respond to risk in a resilient way. It is not being claimed that the network is a model of best practice but it presents an excellent example of a participatory approach to risk reduction in a real world setting, with its organic development, ability to both adapt to change and to span across different continuums of participation in disaster risk reduction. Gathering evidence about the development, limitations, challenges and successes of such initiatives is vitally important for the wider DRR community and should be prioritised in other locations.

Endnote

^aThe notion of 'community' has generated a large body of social science research, characterised by a wide variety of interpretations and perspectives; however, in this paper the term is used pragmatically to refer to collectivities of people living in more or less spatially bounded groupings at a local geographical scale, whether these coincide with officially designated administrative units or are constituted by smaller clusters of dwellings which nevertheless have self-identified social and spatial boundaries.

Additional file

Additional file 1: *Vigía* interview questions and topic guide.

Abbreviations

CBM: Community-based monitoring; CBDRM: Community-based disaster risk management; DRR: Disaster risk reduction; PDRA: Participatory disaster risk assessment; PRA: Participatory rural appraisal; CBEWS: Community-based early warning system; SNGR: Secretaría Nacional de Gestión de Riesgos (National Secretariat for Risk Management, Ecuador); IGEPN: Instituto Geofísico, Escuela Politécnica Nacional (Institute of Geophysics, National Polytechnic School, Quito, Ecuador); OVT: Observatorio del Volcán Tungurahua (Tungurahua volcano observatory).

Competing interests

The authors declare that there are no competing interests.

Authors' contributions

JS conducted the interviews, participant observation, performed the analysis and drafted the manuscript. JB & PS assisted with the analysis and drafting of the manuscript. PC and SCL contributed towards the discussion and reviewed the manuscript. PR and PM facilitated fieldwork in Ecuador, reviewed the manuscript for accuracy, provided data for figures and additional information about the network. All authors read and approved the final manuscript.

Acknowledgements

The authors are extremely grateful for all of the *vigías* who were interviewed as part of the research. The research would not have been possible without the support of IGEPN and in particular the boundless enthusiasm and insight of Wilmer Merino – who acted as a field assistant and interpreter. The authors are grateful to Liliana Troncoso and Javier Jaramillo for facilitating fieldwork and access to local officials. The authors would like to thank three anonymous reviewers whose suggestions helped to improve the manuscript. The research was funded as part of an ESRC-CASE PhD studentship, with fieldwork funding from the British Geological Survey.

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Received: 23 March 2014 Accepted: 31 July 2014

Published: 16 August 2014

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doi:10.1186/s13617-014-0011-9

Cite this article as: Stone et al.: Risk reduction through community-based monitoring: the *vigías* of Tungurahua, Ecuador. *Journal of Applied Volcanology* 2014 **3**:11.