# The roles of participatory monitoring in reducing risk around volcanoes

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# Abstract

This thesis examines the roles of participatory monitoring in reducing disaster risk around volcanoes, by the production of knowledge, enhancing the provision of early warnings, and stimulating risk reducing adaptations. Citizen participation in processes that manage and reduce risk is thought to be essential for building resilient and sustainable development. This thesis addresses gaps in theoretical and practical understanding of the roles of citizens in the production and use of knowledge through participatory monitoring, and the roles of participatory monitoring in reducing risk.

Findings are presented from a global survey of citizen participation with volcano monitoring institutions, comparing across different volcanic, cultural, and risk governance settings. It describes how many of the institutions' motivations are focused on knowledge production and relational trust benefits, but that most initiatives are ad-hoc and reactive to eruptive events, and thus unlikely to quite deliver the expected benefits.

Using an in depth case-study on risk reduction through a community-based monitoring network around volcán Tungurahua, Ecuador, the roles of participatory monitoring at a community scale are analysed. The network grew organically and has multiple risk reduction roles through knowledge production, early warning, enhanced risk awareness, fostering trust-based relationships between scientists and communities, facilitating risk reducing adaptations at community and district levels to multiple hazards.

The contextual influences on participatory monitoring are identified using in depth case-studies of participatory monitoring through long-lived eruptions at two volcanoes: Soufrière Hills Volcano, Montserrat; and volcán Tungurahua. Findings show the importance of the risk context, how risk is managed, the ways that monitoring institutions learn, and the effect of these influences on each other and on the agency of citizens.

The thesis demonstrates that participatory monitoring and participating citizens can have multiple risk reducing roles through knowledge production, knowledge communication, and the actions that can be taken based on knowledge.

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In memory of Benigno:

Benigno Meneces was a *vigía* of Tungurahua. On several occasions he stood ringing the church bell to sound an evacuation of his community, often with volcanic bombs raining down and setting fire to buildings. He risked his life to make others safe. He did it not out of selfish ambition, but out of a deep routed sense of purpose and duty to his family, friends, volcanologists and others. Benigno epitomises what participatory monitoring is all about: it has real purpose, it reduces risk, it brings people together. Benigno touched the lives of many, and at the end of his long battle with cancer, he left behind not just those he worked with, or those living on the slopes of Tungurahua, but many more people who are inspired and hopeful of ways that risk can be reduced with and by people.

> *"For wisdom will enter your heart, and knowledge will be pleasant to your soul. Discretion will protect you and understanding will guard you",*
> *Proverbs 2:10-11*

# Chapter one

# Chapter 1: Introduction

> *"My uncle was stationed at Misenum, in active command of the fleet. On 24 August, in the early afternoon, my mother drew his attention to a cloud of unusual size and appearance. He had been out in the sun, had taken a cold bath, and lunched while lying down, and was then working at his books. He called for his shoes and climbed up to a place, which would give him the best view of the phenomenon. It was not clear at that distance from which mountain the cloud was rising (it was afterwards known to be Vesuvius); its general appearance can be best expressed as being like an umbrella pine, for it rose to a great height on a sort of trunk and then split off into branches, I imagine because it was thrust upwards by the first blast and then left unsupported as the pressure subsided, or else it was borne down by its own weight so that it spread out and gradually dispersed. Sometimes it looked white, sometimes blotched and dirty, according to the amount of soil and ashes it carried with it. My uncle's scholarly acumen saw at once that it was important enough for a closer inspection, and he ordered a boat to be made ready, telling me I could come with him if I wished. I replied that I preferred to go on with my studies, and as it happened he had himself given me some writing to do." An extract from 'The letters of the Younger Pliny' (2003).*

Pliny the Younger provides what are arguably the most famous descriptions of a volcanic eruption ever written, in letters to Roman officials following the AD79 eruption of Vesuvius that killed his uncle and many in the towns and city surrounding the volcano. Pliny's description of the eruption including its (now named) 'Plinian column', and his inferences of the dynamics of dangerous column collapse pyroclastic density currents have provided considerable insight and risk reducing information to volcanologists in modern times (Sigurdsson et al. 1982). Pliny was a non-professional scientist, and is unlikely to be the first 'citizen' to make observations about a volcanic eruption, and was certainly not the last to do so. Indeed, until science became 'professionalised' in the 19$^{th}$ Century, most of the observations or monitoring of volcanic activity were made by citizens. Since that time, the study of volcanology developed as a subset of geology, and now there are many professional volcanologists monitoring or doing research on volcanoes. Are all those that monitor volcanoes professional scientists? What roles can modern day citizens play?

## 1.1 The problem with volcanoes

**Figure 1-1 The Soufrière Hills Volcano at sunset, December 2009**

Whilst being extraordinary natural phenomena to witness (Figure 1-1), very few terrestrial volcanoes erupt in complete isolation without affecting the ways of life of people living both near and far (Sigurdsson et al. 2015). Many people manage to live with them however, in some cases thriving from the fertile lands or micro-climates that they sustain (e.g. (Kelman and Mather 2008; Chester et al. 2012), but in historical times eruptions have destroyed entire towns (Voight 1990), cities (Druitt and Kokelaar 2002), and affected global climate (Oppenheimer 2003). It has been over thirty years since the last major volcanic disaster (Barclay et al. 2008), a hiatus that could be explained by significant advancements in volcano monitoring (Sparks et al. 2012), risk management successes (e.g. Surono et al. 2012), or as a result of the paucity of eruptions when comparing the geological timescales of volcanoes to human history (Auker et al. 2013).

The new Sendai Framework for Disaster Risk Reduction (UNISDR 2015a) calls for the engagement of all levels of society in the process of Disaster Risk Reduction (DRR) or Disaster Risk Management (DRM), with particular reference to early warning systems, and to the roles of citizens and volunteers. There is increasing recognition of the potential danger from volcanoes, and the importance of volcano monitoring in DRR (UNISDR 2015b), but to date there is limited work on how citizens might participate in the processes of DRR around volcanoes, particularly their potential roles in volcano monitoring.

Concurrently, many suggest that the participation of citizens in decision making about risk increases rigour (Stirling 2007) and others say that for decisions that have uncertain outcomes with high stakes, citizens must form part of an extended peer community (Funtowicz and Ravetz 1993). Irwin (1995) suggests a new form of science called ‘citizen science’ where science is both for citizens and carried out or directed by citizens. Citizen science, of which participatory monitoring can be considered a form, has grown into its own discipline, describing processes where citizens design the research, or collect, analyse, or interpret data (Conrad and Hilchey 2011; Haklay 2012). It has been demonstrated that citizens can collect good quality data (Tulloch et al. 2013), produce knowledge that leads to scientific discoveries (Bonney et al. 2014) and that participation in citizen science can lead to community ownership of problems (Conrad and Hilchey 2011). Thus far, there are very few examples of initiatives described as citizen science or participatory monitoring in volcanology or DRR more generally.

This thesis addresses these gaps in theoretical and practical knowledge by addressing a central research question: what are the roles of citizens in reducing risk around volcanoes through participatory monitoring? The findings are situated within the context of DRR more broadly, and the outcomes of the thesis will therefore be of use to volcano monitoring institutions, researchers, citizens, disaster risk managers, and Non-Governmental Organisations (NGO). It will also have wider relevance for risk reduction from other natural hazards.

## 1.2 Aims and objectives

The principal aim of this thesis is to understand how, when, and why citizens participate in monitoring volcanoes, predominantly through collaboration with volcano monitoring institutions, describing their potential roles and whether or not their involvement leads to enhanced risk reduction. To achieve these aims, the following objectives will be addressed:

- To understand the roles of citizens in DRR processes; identifying existing and developing new theories to apply to a volcano context.
- To understand the different ways that citizens may participate in monitoring processes with volcano monitoring institutions, across multiple contexts.
- To examine the outcomes of citizen participation, and how they may lead to risk reduction.
- To explore the impact that participatory monitoring has when embedded within a community.
- To investigate the ways and pathways by which participatory monitoring may lead to other forms of participation.
- To understand what forces shape the roles that a citizen may have in participatory monitoring.
- To synthesise learning that can assist with the development of effective DRR/DRM strategies in volcanic areas.

The research will focus on citizen participation in monitoring for four reasons: i) risk from volcanoes can be significantly reduced through monitoring and effective early warning; ii) whilst other work has focussed on community engagement with volcanic risk reduction, the potential roles of citizens in monitoring is yet to be studied in depth; and iii) in other fields, citizens participating in monitoring activities (often called 'citizen science'), has generated numerous benefits, suggesting that there may be untapped (or yet to be described) potential around volcanoes, iv) the predominant focus of the thesis on citizens collaboration with volcano monitoring institutions, and the nature of those interactions, may yield important insight for other fields.

## 1.3 Theoretical and methodological approach

At the start of this PhD the author had a first degree in Geology, a Masters degree in the Science of Natural Hazards and a Masters degree in Environmental Social Sciences, along with practical and professional experience of volcanology. Volcanology is now considered by many to be its own discipline, drawing on learning from many areas of research and practice (Barclay et al. 2008; Donovan 2010; Johnston 2012). This thesis therefore, is approached from an interdisciplinary viewpoint, but the methodologies chosen for addressing the aims and objectives listed above are predominantly qualitative social science methodologies. The focus during data collection and analysis is therefore on words, rather than quantification, as the thesis seeks to describe social processes and inductively develop theory from the research findings (Bryman 2012).

The term 'mixed-method' is increasingly used to describe combinations of qualitative and quantitative methodologies (Bryman 2012), and whilst Chapter 3 uses some quantitative analysis, the thesis as a whole predominantly uses a mixed-method qualitative approach (Bernard and Ryan 2009). The use of different methods mean that findings can be cross-checked through triangulation, increasing the internal and external validity of the conclusions generated from this research (Bernard and Ryan 2009).

## 1.4 Thesis structure

This thesis draws theory together from different fields to describe and understand the risk reducing roles of participatory monitoring around volcanoes. Each chapter provides different but interrelated perspectives on the central research question. The final chapter discusses the implications of the previous chapters and integrates the contributions that they make. Therefore, with the exception of Chapters 1 and 6, each of the chapters are structured in the form of a research paper, including (but not necessarily named as such) the following sections:

- Introduction/background,
- Methods section (except Ch2),
- Results,
- Discussion,
- Conclusions.

***Chapter 2*** synthesises background literature on citizen participation, drawing on work from science and technology studies, international development, citizen science and DRR. It examines existing theoretical frameworks that could be used to understand the roles of citizens in monitoring volcanoes, before outlining a new theoretical framework that bridges the gaps between the other frameworks.

A global perspective is then used in ***Chapter 3***, to map out the extent to which citizens participate in the activities of volcano monitoring institutions at many of the world's volcanoes. Evidence is presented from a global survey to address the following research questions:

- Why, when and how do citizens participate in volcano monitoring?
- Why do some institutions choose not to or are unable to work in this way?

- What are the perceived likely or actual outcomes of these collaborations?

The answers to these questions are discussed, drawing on evidence from multiple contexts. Recommendations are then made, so that learning can be shared across these different contexts and so the potential benefits of participatory monitoring can be best achieved.

The focus is sharpened in ***Chapter 4*** to seek in depth understanding of how participatory monitoring can contribute to DRR, by describing and analysing a well-established community-based risk reduction initiative in Ecuador. This chapter, reproduced verbatim from a research article (Stone et al. 2014b) that was published in year 2 of the PhD, describes how a participatory monitoring network led to significant risk reducing benefits for communities around Tungurahua volcano, Ecuador. Attention is given to describing the multiple roles of the participants, known as *vigías*, in DRR processes, and the strong trust-based relationships that are developed between citizens and scientists as a result of the network. The chapter also presents material that is additional to Stone et. al. (2014b), including the impact of the research and a feedback workshop in Ecuador.

***Chapter 5*** then uses the lenses of two long-lived eruptions at Tungurahua, Ecuador and Soufrière Hills Volcano, Montserrat, to examine: how do the drivers of and barriers to participatory monitoring change with time and context? It draws on learning from the previous chapters and the wider literature on resilience, risk governance, and risk management to analyse: what are the factors which open or close spaces for participatory monitoring in the two case-studies? It considers the recommendations from *Chapter 3* with respect to the two eruptions, and discusses ways in which the potential risk reducing benefits of participatory monitoring might be realised, despite contextual challenges.

Learning from the previous chapters is synthesised together in ***Chapter 6***, and the potential value and roles of participatory monitoring around volcanoes is discussed. A new conceptual framework that describes the potential of participatory monitoring to reduce risk is presented that situates the findings of the thesis within the context of DRR more generally, from which important avenues for future research are highlighted.

# Chapter two

# Chapter 2: Understanding the roles of citizens in disaster risk reduction

## 2.1 Introduction

This thesis investigates how citizens may reduce risk from volcanoes by participating in community-based monitoring of volcanic hazards. Some of the hazards that occur in volcanic areas are specific to volcanoes, others are not, but often the factors that drive vulnerability and exposure, such as inequality, poor risk governance, and a lack of early warning, are common across different disasters.

Disaster risk reduction is a systematic process aimed at reducing the adverse effects of natural hazards. This can be achieved by strategies such as: understanding the causes of disasters; promoting strategies that limit exposure; reducing vulnerability; enhancing early-warning; and by improving preparedness for future events. DRR is of critical importance for the development of sustainable and resilient societies (IPCC, 2012; (Lavell and Maskrey 2014; UNISDR 2015b). Risk is not just an immediate problem associated with an actual event; citizens are impacted by both interactions with an immediate hazard and the potential for future hazardous events. Consequently, many decisions that affect ways of life for society are made by, and for, citizens as a response to that risk (Stirling 2007). Thus, responsibility for DRR is distributed across multiple scales, from global organisations to the individual citizen. For some time it has been acknowledged that not only should citizens be involved in the processes of DRR on ethical or normative grounds, but also their involvement has been shown to result in substantive reductions in disaster risk for themselves and wider society (Maskrey 2011;

Scolobig et al. 2015). Citizens can be involved in the process of reducing risk in a variety of ways and to varying extents and different risk governance contexts play a key role in determining the different levels of responsibility and degrees of agency (used in this thesis to describe the capacity of citizens to make their own choices and carry out their own actions) that citizens have to reduce disaster risk for themselves, or to participate in risk reduction processes for others.

To effectively reduce risk, it is of critical importance to be able to understand participatory DRR in terms of who it involves, what it does, and what makes it successful (or unsuccessful). Only by unpicking the factors that shape it can practitioners most effectively reduce risk through involving citizens in the processes of DRR. Citizen participation in DRR suggests that citizens are able to either make or at least inform decisions or actions that are made to reduce risk (Mercer et al. 2008; Pelling 2010; Maskrey 2011; Le De et al. 2014). These decisions are made at all levels, from individual choices through to policies set at an international scale, but the extent to which a citizen is able to make, influence, or inform decisions is shaped by the power that a citizen has (e.g. Arnstein 1969), and therefore many theories of participation use power as their central analytical concern.

Participation, or 'the act of taking part in something' (Stevenson 2010), is an important process that feeds into the ways in which society is produced, changed, and governed. However, many scholars of participation find that it is difficult to define (Rowe and Frewer 2000; Twigg 2004; Pelling 2007; Chilvers 2009). As suggested by Chilvers (2008) there are many words for participation, meaning that as a term or concept it can be confusing, misleading, or misused, and Pelling (2007) describes it as a 'slippery and contested' term. Despite the conceptual fuzziness, in practice participation continues to be used extensively in DRR contexts, and in wider society, where the participation of citizens in governing society is often seen as a political necessity or as a fundamental characteristic of democracy.

The burgeoning literature on citizen participation in DRR draws on a number of different streams of research and practice. These may range from fields associated with international development (typically aligned with sociology, anthropology or geography); decision-science (particularly those fields applied to conditions of uncertainty or risk), and; 'post-normal' science and citizen science. Consequently, within and between these streams the notion of participation – what it is, what it should be defined as, how it should be conceptualised or evaluated, what it does, and how it should be used – is widely contested. These disagreements about participation can either add to the debate, potentially furthering theoretical understanding, or create a conceptual fuzziness that could lead to confusion, misuse, apathy or even manipulation.

To provide an analytical framework for the thesis, this chapter reviews theories for understanding citizen participation in DRR, and discusses how they may be used to understand the different roles that citizens can play in contributing to DRR processes. The chapter provides different perspectives on participation by reviewing four sets of literature: i) the literature on DRR, including how it has evolved, describing its relevant international policy and institutional frameworks, before focusing in on the continued drive for DRR approaches to be people-centred; ii) the literature on participation in international development, of which DRR is a subset; iii) the literature on participation in decision making about science, risk and the environment, and; iv) the literature on knowledge production through activities labelled as citizen science, which will be discussed with respect to the other fields.

This thesis uses the context that arises from viewing participation as a means to reduce individual and societal risk, but as outlined in the previous chapter, focuses particularly on citizens participating in the monitoring of volcanoes. This is a context-specific form of participation, but as will become apparent, the current ways that participation is described or framed in the DRR literature are not necessarily inclusive of activities like participatory monitoring; instead often focusing on participation more as a means of empowerment than for the purpose of knowledge production.

Some scholars advocate  for ideal or even ‘true’ forms of participation (e.g. Le De et al. 2014). Such discourse often applies a normative rationale, rooted in an emphasis on the need to empower the poor to become resilient to an uncertain future and various shocks and stresses. A focus on empowerment and people-centred DRR processes is important, but many of the conceptual frameworks that may be used to describe participatory DRR with this as a primary focus do not adequately capture the full spectrum and importance of the potential roles that citizens can have, and can be particularly deficient in describing roles related to knowledge production. Hence, there is need for a more nuanced approach, to consider participation that has both knowledge production and empowerment as goals. A study of citizen participation should, therefore, consider a broader spectrum of approaches, and determine the extent to which these are effective in achieving the end goal of the reduction of individual and societal risk, whether that comes via empowerment, knowledge production or some combination of both approaches.

To achieve that in this study, the strengths and weaknesses of several conceptual or analytical frameworks are discussed and synthesised. This enables a description and understanding of the roles of citizens in diverse forms of participation, and as discussed in later chapters, is used to unpick the pathways by which citizen involvement in monitoring may lead to effective DRR.

## 2.2 Disaster risk reduction

Despite advances in the scientific understanding of physical hazards, losses from disasters continue to rise as a result of increasing exposure of the most vulnerable, rising inequalities, and the continuing accumulation of risk as a result of poor decision making (UNISDR 2015b). Reducing or managing this risk is clearly a difficult task requiring collaboration between governments, scientists, NGOs, and civil society (Oxley 2013). Disasters have an impact on all nations irrespective of a countries gross economic wealth. The United Nations International Strategy for Disaster Reduction's (UNISDR) 2015 Global Assessment Report on DRR (GAR15) recognises two different categories of risk that can exist for a nation, community, or citizen: intensive risks (e.g. those posed by a potential earthquake), and extensive risks (e.g. those associated with climate change). These different categories are a consequence of different scales of physical processes that drive losses over different time-scales. Intensive risk is often driven by extreme hazards with the losses dominated by the size of the hazard and the exposure, whereas extensive risks are more often characterised by regularly occurring physical events, where the losses are driven by differential vulnerability and the cumulative effect of the hazards. These different hazard processes and timescales, inequalities, and differences in vulnerability and exposure create layers of risk (UNISDR 2015b). The GAR15 report illustrates this by describing several disasters, for example the 2004 Indian Ocean Tsunami, where the size and severity of the hazard, and the exposure of people and assets to it, dominated the risk. This contrasts with a disaster such as that in New Orleans following Hurricane Katrina in 2005, where the losses were driven by pre-existing vulnerabilities and inequalities of risk that had built up over time. Although Katrina was a particularly large hurricane, the potential impacts of such a storm were well known, yet years of inequality meant that the poorest or least mobile people were unable to evacuate in a timely manner. Inadequate governance processes drove disaster in a third example: the 1985 eruption of Nevado del Ruiz, Colombia, where lahars killed over 23,000 people (Voight 1990; Barclay et al. 2008; UNISDR 2015b). Here, despite sound and timely scientific warning, a known possible hazard footprint, and a hazard travel time to exposed population of over two hours after the initial eruption (for the majority of fatalities), a lack of coordinated or coherent risk management plans and actions meant that a very limited number of evacuations took place, leading to a massive loss of life.

In all of the disasters described above, many of the fatalities and losses, in hindsight, could have been far fewer. For two of the cases, improved early warning systems, either through infrastructure or improved governance and communication, would have facilitated timely evacuations, and in the other, recognising and addressing long-standing and entrenched vulnerabilities would have saved the lives of many.

Faced with the complex processes that drive disasters, reducing or managing the risks from them requires collaboration between many different stakeholders. Many suggest that DRR should be mainstreamed into development and in turn that international frameworks for the implementation of DRR strategies should then include other priority areas such as climate change adaptation and conflict (Oxley 2013; Carabine 2015; Kelman et al. 2015). Efforts to mainstream DRR into wider development processes have been occurring for some time, but scholars suggest that progress is too slow (Pelling et al. 2004; Pelling 2010; Lavell and Maskrey 2014; Carabine 2015; UNISDR 2015b).

Despite several decades of evidence to the contrary, many still describe disasters as being natural disasters, i.e. caused by extreme natural events (Lavell and Maskrey 2014). However, as discussed above, such disasters are not simply natural, but occur as a result of physical (or technological) hazards impacting on exposed or vulnerable citizens, with the severity of impact influenced by social inequalities, poor governance systems, accumulated risk, and the frequency or magnitude of the hazard. Recognising the complexities of disasters and disaster risk, various international frameworks for DRR maintain that citizens, i.e. those affected by disasters, should therefore be centrally involved in DRR decisions and implementation (e.g. UNISDR 2005; UNISDR 2015a).

### 2.2.1 Who is responsible for DRR?

Many different actors have potential roles and responsibilities in reducing risk, across multiple scales, from national governments to individual citizens (Wilkinson et al. 2014). Whoever has the responsibility, evidence suggests that DRR can save lives, money and 'life years' (Twigg 2004; Tweddle et al. 2012; Shreve and Kelman 2014; UNISDR 2015b; Tanner and Rentschler 2015). Variations in the sharing of responsibilities are often due to differing forms of disaster risk governance, which is defined by the United Nations Development Programme (UNDP) as:

> *'the way in which the public authorities, civil servants, media, private sector and civil society coordinate at community, national and regional levels in order to manage and reduce disaster and climate-related risks. This means ensuring that sufficient levels of capacity and resources are made available to prevent, prepare for, manage and recover from disasters. It also entails mechanisms, institutions, and processes for citizens to articulate their interests, exercise their legal rights and obligations, and mediate their differences.' (UNDP 2013)*

This differs from disaster risk management, which describes a particular set of actions that are intended to achieve the objective of disaster risk reduction (UNISDR 2015b). These actions may include steps that mitigate the potential effects of hazards, measures that reduce vulnerability (such as the retrofitting of structures to make them more resistant to earthquakes), or actions that limit exposure to hazards through monitoring and early warning. It is therefore logical that the ways in which disaster risk is governed affect the ways in which it is managed. The manner of risk governance and the ensuing distribution of responsibilities between the state and citizens has been shown to affect the latter's perception of their agency for reducing risk themselves or participating in risk reducing processes (Bickerstaff et al. 2008; Scolobig et al. 2015). The effect that different governance styles have on participation has been recorded by studies focussed on international development (Hickey and Mohan 2004), in DRR (Wilkinson et al. 2014; Lavell and Maskrey 2014) and in forms of risk governance in volcanic areas (Wilkinson 2013; Wilkinson 2015).

Strong theoretical justifications for participatory forms of DRR have been presented: these include more equitable and successful strategies to reduce and manage disaster risk, and will be discussed in more detail in section 2.4. Nonetheless there are still only limited published examples that present evidence for where, how, and why it has been successful (Pelling 2007; Maskrey 2011; Cadag and Gaillard 2012; Gaillard and Mercer 2013). Scolobig et al. (2015) suggest that there is a need to balance the rhetoric of participatory DRR with the reality. They suggest that the reality is that, despite it being normatively the right thing to do, with its potential to lead to better outcomes, participation often has what they describe as '*teething problems*', mostly related to the sharing of risk governance and management responsibilities between established risk management institutions (where they exist or function) and citizens. This metaphor from child development suggests that participatory DRR is still in its infancy, rather than attributing some of its problems to the rather more fundamental and durable problems resulting from the pre-existing relationships between a state and its citizens in any one context. Scolobig et al. (2015) identify that there needs to be a better understanding of citizens' perspectives and expectations of responsibility, suggesting that the roles of different actors are often not clearly defined. They also note that disaster risk managers need to be better communicators, re-examine existing institutional ways of working, and be willing to engage in long-term dialogue and collaboration with citizens. Again, however, many of these issues reflect broader and more fundamental challenges that are often present in the relationship and interactions between citizens and the state (Bickerstaff et al. 2008), which in a disaster context manifests itself in risk governance.

### 2.2.2 Why does DRR often focus on citizens and community?

In this thesis the subjects are characterised as *citizens*, a term that reflects an individual's political identity in terms of their intendant rights and responsibilities, rather than focusing on them as *lay-people* or the *public*. A lay-person emphasises an identity in relation to official systems of knowledge and expertise, and public posits a collective identity in the sphere of public communication and debate. Whilst there can be no 'value-free' term, other than individuals, the focus on citizens emphasises that their responsibilities are normally different to those of the state, without making any assumptions about the extent or forms of knowledge that they possess (Irwin 1995). A citizen is an individual with a degree of agency that she or he can use, within the structures that she or he lives, to make decisions and actions. By focussing on citizens, it is possible to understand their roles both individually, and collectively as members of communities, organisations, and institutions.

Later the thesis will refer to *community-based* (the scale), and *monitoring* (as the process that citizens are participating in), which may also involve other stakeholders, such as scientists, authorities, or NGOs, to greater or lesser extents (Figure 2-1). There are of course other scales at which citizens can participate in DRR, from the individual or household, through to national and international scales, and whilst participation across and within all of these scales is important (Lavell and Maskrey 2014) this chapter will mainly focus on citizens and communities, as many scholars suggest that at this scale there can be significant DRR as a result of participation (Maskrey 1989; Delica-Wilson 2005; UNISDR 2005; Pelling 2007; Mercer et al. 2008; Maskrey 2011; UNISDR 2015b).

The notion of 'community' has generated a large body of social science research, characterized by a wide variety of interpretations and perspectives (e.g. (Etzioni 1996)); however, in this thesis 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.


**Figure 2-1 Community based monitoring - describing a scale and a process**

As intimated so far, DRR is considered by many to be an essential facet of sustainable international development (UNISDR 2015b), indeed, the reduction or management of disaster risk is featured prominently in the key targets for three of the Sustainable Development Goals (United Nations 2015). Thus when examining participation within DRR, it is useful to first consider participation from the perspective of international development (methodologies, practice and theory), given its somewhat paternal relationship to DRR.

## 2.3 Perspectives on participation from international development

The drive for participation in international development is in opposition to more technocratic methods for analysing poverty and implementing solutions, in ways that are *with* and *by* people, rather than *to* or *on* them (Cornwall 2000). Whilst many of the societal decision making issues that participation is used to address are the same for developed and developing countries, participation in international development is primarily concerned with poverty eradication (Hickey and Mohan 2004). Participation in development also tacitly assumes or acknowledges the absence of a responsible or functioning state and is often motivated by a desire to change this (Hickey and Mohan 2004). Much of the theory and practice for participation in DRR comes from the field of international development, where it became mainstreamed several decades ago (Hickey and Mohan 2004). Despite major criticisms of how and when participation is used (e.g. Cooke and Kothari 2001), it remains embedded in almost all development programming. Hickey and Mohan (2004) suggest that within development, participation has been used for a variety of purposes, ideologies and political projects. Many cite the emergence of participatory rural appraisal (PRA) (Chambers 1994) as a driver for a mainstreaming of participation in development. PRA "*describes a growing family of approaches and methods to enable local people to share, enhance and analyse their knowledge of life and conditions, to plan and to act"* (Chambers 1994). It was born in response to more technocratic approaches to development such as rapid rural appraisal (RRA), which tended to be outsider driven, expert dominated elicitation exercises, that potentially lacked contextual understanding and relevance, and where solutions that arose out of RRA were less likely to be effective for communities and citizens. Participatory approaches to development should recognise that local people have not only rich and valuable knowledge to contribute, but also creative and analytical abilities to lend to their process of poverty eradication. PRA and many participatory approaches to development imply or insist on fundamentally different roles for the expert, where she or he is no longer eliciting opinion, but rather facilitating the expression of opinion, meaning that the community is able to shape the conversation and rely on the expert as a resource. There is a considerable body of evidence to suggest that these processes are very effective, when carried out as intended (Hickey and Mohan 2004), yet prone to misuse (Cooke and Kothari 2001).

This has clear similarities with tensions between theory and practice in the analysis of participation in science and society that follows. Furthermore, it has been suggested that participatory methods that focus on knowledge production (e.g. PRA) don't necessarily generate data of a lower quality or efficacy than expert methods.  Participatory methods have the potential, if needed,  to collect the type of quantitative data that are often preferred by technical experts, at a larger scale (Mayoux and Chambers 2005). Further, 'participation' has the ability to enhance citizens' agency, by renegotiating responsibilities, and reducing inequalities of power and opportunity (Gaventa 2006). Agency is thought to be essential for building resilient communities (e.g. Pain and Levine 2012). This potential, to reduce risk via effective and equitable participation, is something citizens, practitioners, experts and decision makers all stand to gain from.

Despite the strong ideological rationales for participation and the evidence of substantive outcomes from where it has been done well, strong criticisms have been levelled at it. Participation in development has been accused of becoming a new form of tyranny, where it has the potential to be used as an instrumental tool to prolong or disguise rather than reduce inequality (Cornwall 2000). Even without deliberate manipulation, the voices of the most marginalised are often not heard because of issues surrounding representativeness and inclusion often present in participatory processes (Cooke and Kothari 2001). Many of the critiques applicable to participation in development, are also applicable to participatory DRR, and will be discussed in more depth in subsequent sections.

## 2.4 Participation in DRR

In a similar vein to international development, participation has also been mainstreamed into DRR strategies, with an expectation that citizens will, are able to, or at least should play some role in reducing disaster risk to themselves, their family or livelihoods. Many scholars and practitioners advocate for 'people centred' DRR (e.g. (Wisner et al. 2004; Kelman et al. 2011; Mercer et al. 2012b; Scolobig et al. 2015; UNISDR 2015b)) used as a means to describe approaches that put those at risk at the centre of initiatives to reduce risk. Many frameworks advocate for people centred approaches to focus at a community scale (UNISDR 2005; Gaillard and Mercer 2013; UNISDR 2015a).

One of the challenges for researchers, practitioners, authorities or citizens trying to understand participatory DRR is that very often there are different names and worse still – different acronyms - for what ostensibly may seem to be the same thing. Similarly, names for related processes can change with time, as is the case with Community Based Disaster Risk Mitigation (Maskrey 1989); subsequently replaced with Community-Based Disaster Risk Management (CBDRM) (Maskrey 2011). Nevertheless, the vast number of terms for participation reflects the depth of work that has a focal desire to be carried out in collaboration with or by citizens (Pelling 2007).

In the same way that disaster risk reduction requires disaster risk management (UNISDR 2015b; UNISDR 2015a), community-based disaster risk reduction (CBDRR) is often best achieved through community-based disaster risk management. In these people centred approaches, the people, or the citizens, can fulfil a number of different roles that help to reduce risk, either at a community-level, or through networking horizontally with other communities and by linking vertically to other scales of risk reduction and management (Lavell and Maskrey 2014). The selection of different approaches detailed below reflect the varied roles that citizens may have in DRR processes; some of them overlap and in many cases describe different foci of scale. Some of the processes that could be described here have limited examples explicitly within the DRR context. This is particularly the case with initiatives labelled as citizen science, which is described separately in section 2.6.

### 2.4.1 Community-based DRR

For some time there has been a drive for managing disaster risk at a community-scale, where communities are able to plan for and respond to future hazards (Maskrey 1989). As theory and practice have evolved, the role of regional and national authorities in helping communities manage risk has also been recognised (Maskrey 2011; Wilkinson et al. 2014; Lavell and Maskrey 2014), thus CBDRR/M initiatives should ideally be vertically integrated to other risk management plans and processes at other scales, if they are to be most effective. Maskrey (2011 p.48) states that *'the underlying rationale is that there is empowerment of and ownership by local stakeholders, either at the community or municipal level that should lead to a sustainable reduction in disaster risks over time'.*

Maskrey goes on to quote Albarquez and Murshed's (2007) definition of CBDRM:

> *'the process of disaster risk management in which communities at risk are actively engaged in the identification, analysis, treatment, monitoring and evaluation of disaster risks in order to reduce their vulnerabilities and enhance their capacities. This means that people are at the centre of decision-making and implementation. The involvement of the most vulnerable is paramount and the support of the least vulnerable necessary. Local and national government are involved and supportive'.*

What is quite clear from the literature on CBDRR and CBDRM is that by anchoring it to the community-scale, there is an assumption that it should be an empowering process for the community, where they themselves gain from being involved in terms of risk reduction for themselves. The tacit assumption is that 'community-based' means that the knowledge produced has primary value for the community and only secondary value elsewhere. Maskrey describes local level disaster risk management, carried out by local authorities, as slightly different, which although it can promote CBDRM, is less likely to function well in cases where local authorities are under resourced to managed risk locally, in which case CBDRM is needed ever more. Maskrey (2011) stresses that we need to move beyond top-down and bottom-up framings of technocratic vs. participatory or community-based, but instead look towards collaborations that make or strengthen linkages between different actors at differing scales, from communities, through to the national level, and citizens through to technical experts.

There is a growing body of evidence suggesting that community-based management of disaster risks can be very effective, i.e. with landslides (e.g. Holcombe and Anderson 2010; Karnawati et al. 2011), flooding and coastal hazards (e.g. Delica-Wilson 2005), volcanoes (e.g. Donovan 2010; Cronin et al. 2004b) of which many of the CBDRM initiatives are across multiple hazards (Gero and Méheux 2011; Cadag and Gaillard 2012; Mercer et al. 2012a; Gaillard and Mercer 2013). CBDRM can often also be called *participatory DRR* or *participatory disaster risk management*, when there is no attachment to scale.

### 2.4.2 Participatory Disaster Risk Assessment

Community-based disaster risk reduction doesn't just happen, but requires communities to use a number of techniques or tools that help them to identify potential hazards and vulnerabilities; plan for how they may issue early warnings; respond to hazards; and thus mitigate against risks, including ways in which they may access support from elsewhere (Twigg 2004). Therefore, there are a number of techniques wrapped up in approaches labelled as Community-based DRR, such as Participatory Disaster Risk Assessment (PDRA). The processes that make up PDRA (e.g. those listed in Pelling (2007; and in 2.7.2) describe some of the processes involved in other forms of participation. Again, the boundaries between different forms of participation are extremely fluid and terms are often interchangeable. The objective of PDRA is to help inform risk management planning and actions by providing contextually grounded information about risk, thereby facilitating risk reduction. PDRA as a suite of processes will be discussed in more detail in section 2.7.2, where Pelling's (2007) conceptual framework will be discussed and evaluated for use more widely in understanding participation in both DRR more generally, and in community-based monitoring.

### 2.4.3 Community-based Early Warning Systems, and Community-based Monitoring

Both the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction (SFDRR) state that early warning of physical hazards is essential for DRR (UNISDR 2005; UNISDR 2015a). They advocate that early warning systems (EWS) have the potential to save lives and reduce impacts on assets (e.g. Garcia and Fearnley 2012). Early warning systems come in a variety of shapes and sizes, from local level flood warning through to systems that span the globe, such as the Pacific Tsunami Warning Centre (PTWC) (Bernard et al. 2006). In some situations the warning system is local, or located in the community, as is often the case with volcano observatories (discussed in more detail in Chapter 3). Many early warning systems rely on the participation of citizens at some level, and some are built around their participation (e.g. the *vigías* network in Ecuador, Chapter 4). Garcia and Fearnley (2012) describe how early warning systems often incorporate hazard monitoring, risk assessment, forecasting and risk communication. They suggest that often, critical links between components are missing, which can lead to catastrophic failure, as was the case in Armero (Voight 1990). Citizens have demonstrated considerable potential to link these components together (Zschau et al. 2003; Goodchild 2007; Mothes et al. 2015), and early warning systems embedded within communities have led to risk reduction in many areas (Karnawati et al. 2011; Cadag and Gaillard 2012; Stone et al. 2015). Citizens may participate in different facets of an EWS, for example in the case of community-based early warning they may take part in community-based monitoring activities, producing knowledge about particular hazards (e.g. Stone et al. 2015; Cronin et al. 2004a; Karnawati et al. 2011; Conrad and Hilchey 2011; Bernard 2013), in some cases they also operate sirens (e.g. Cadag and Gaillard 2012), and/or take part in risk assessment (PDRA). Indeed, often community-based early warning systems form the majority of CBDRR activities.

### 2.4.4 Participation in DRR around volcanoes

As mentioned throughout the thesis, there are limited examples of participatory DRR around volcanoes in the literature. These approaches can be classified into three groups, by considering the actors involved (who is predominantly participating with whom): i) volcano monitoring institution and citizen participation, ii) citizens and researchers (who may be volcanologists), and iii) citizens and NGOs or other civil society organisations. These distinct groups represent end members, in reality initiatives may involve all three groups of stakeholders, but separating approaches via the key drivers and beneficiaries in this way allows for some critical analysis.

Two of the earliest and most notable initiatives are documented in papers by Cronin et al. focussed on the Solomon Island (Cronin et al. 2004a) and Vanuatu (Cronin et al. 2004b). In both examples they used a modified version of participatory rural appraisal (PRA). This mostly consisted of activities that are common place in PRA, PDRA or vulnerability capacity analysis (VCA) approaches. There were a series of participatory activities within the community which included transect walks, community mapping, focus groups and sessions of direct discussion between citizens and scientists. The participants included authorities, citizens, research scientists, and representatives from a volcano observatory involved to varying extents in different activities. Following the workshops in Savo, Solomon Islands, outcomes were reported as increased trust between stakeholders and indications that communities would take some risk reducing adaptations (Cronin et al. 2004a). In Vanuatu, the reported outcomes were modified community emergency plans and updated VMI Alert Level plans (related to early warning). What neither of the publications suggest are signs of longer term outcomes benefits (or monitoring of outcomes). Both initiatives were funded by a discrete (time-bounded) project so no continuing participation was resourced.

Donovan (2010) carried out participatory work in communities around Merapi, Indonesia to explore culture and risk reduction. The work involved various research methodologies, and participatory tools such as community-mapping and transect walks. Outcomes included a community emergency plan. Again, like Cronin (2004a; 2004b) this formed a discrete time-bounded project and so there is no mention of longer term outcomes, beyond the new research insight.

Bowman and White (2012) describe the DRR interventions of NGOs around Santa Ana volcano in El Salvador. They observe the 'transient' and 'nebulous' training and preparedness activities carried out, with limited evidence of long-term impacts. They also lament the lack of coordination with local volcano-monitoring scientists. They note that one-off workshops, focussing on planning or education appear to have limited impact on risk reduction. This adds further weight to arguments for participatory initiatives that are based on regular engagements over time, and coupled with science processes. Further participatory DRR initiatives, which are closer in nature to citizen science and participatory monitoring are discussed in subsequent sections.

## 2.5 Perspectives on participation from risk, science and society research

It is helpful to set participation in DRR within the context of the wider literature on participation, particular the perspectives of research about risk, science and society. An interest in citizen participation is particularly evident in literature describing decision-making processes about risk, be that about science or technology usage for and by society, or with naturally occurring physical hazards. A focus on risk suggests that there is some uncertainty about the outcome of a decision, which could be an opportunity for either gain or loss. Risk can be framed, analysed and acted upon in varying ways by different groups (e.g. Tversky and Kahneman 1974; Slovic 1987; Renn 1992; Slovic 1993; Fischhoff 1995; Stirling 1998; Joffe 2003; Wynne 2005; Gaillard 2008; Paton et al. 2008; Haynes et al. 2008a; Scheer et al. 2014). Framing here refers to the ways in which individuals make sense of or construct and create meaning about a particular concept. Some predominantly frame risk as an opportunity for gain (e.g. those working in the financial industry), others view it as the potential for loss (e.g. in DRR), and are likely to have different preferences for how decisions about risk are made (Tversky and Kahneman 1974).

### 2.5.1 Re-thinking who should be involved in making decisions about risk

Decision-making by those who act to govern society, is often based on evidence collected through scientific investigations, particularly when those decisions can affect the ways of life of citizens. Citizens can participate in decisions making processes, by deciding on what scientific knowledge is necessary, help to produce that knowledge and then help make decisions based on the evidence produced.

Fiorino (1990) suggests that there are three rationales for the involvement of citizens in activities that make up decision-making processed: normative, substantive, and instrumental. A normative or ethical rationale for participation is that, to be consistent with democratic principles and to foster a democratic culture, citizens should be involved in the decisions that affect their lives (Freire 1981; Renn and Webler 1995). A substantive rationale suggests that participation leads to better outcomes in a decision making process (e.g. those described by Stirling 1998; Stirling 2007; Funtowicz and Ravetz 1993). An instrumental rationale describes participation as a tool, which helps placate ill-feeling and move citizens towards accepting or justifying a decision, or building consensus. Whilst instrumental uses of participation can be manipulative, an instrumental rationale is not necessarily negative if participation is used to develop consensus towards something that is objectively good for society (Wynne 2006). Scholars such as Webler (1995) also suggest that participation facilitates learning about the topic in question. This learning can be both between and within the stakeholder groups that are involved in the process and then also shared by the stakeholders with the wider community. As will become clear through the chapter, these rationales can apply to any given example, with a caveat that a participatory initiative may at different times be shaped by different rationales, enacted or experienced from the points of view of multiple stakeholders.

In many systems of governance those with technical knowledge make or strongly influence decisions; an approach to governance described as 'technocracy' (Fiorino 1990). Forms of governance like this, where the locus of responsibility for managing different sources of risk is solely on the state, have been shown to reduce citizens' perception of their ability to reduce risk for themselves (Bickerstaff et al. 2008). The norm of technocratic risk governance in many countries means that traditionally decisions about risk have been firmly in the domain of experts (Stirling 1998), with formal methods or techniques such as probabilistic hazard assessments, numerical modelling, or expert elicitation (Stirling 2005; Stirling 2007) dominating discussions. However, Stirling (2007) suggests that the science behind risk assessments may not always be as value free, unbiased, or impartial as their proponents might claim, and argues an imperative for opening up the decisions about risk so that decision makers will understand and attempt to incorporate the framings of all stakeholders in order to achieve greater analytical rigour and more equitable decisions (Stirling 2007). Many scholars present evidence that the views of citizens should be better represented in science or technological issues, rather than dismissed as non-expert opinion (e.g. Slovic 1993; Stirling 1998; Hoffmann-Riem and Wynne 2002; Jasanoff 2004; Wynne 2005; Chilvers 2009).

Funtowicz and Ravetz (1993) point to the limits of technocratic styles of making decisions and suggest that they are not suited to some of the risk problems that society faces. They describe how decisions vary according to the decision stakes and the uncertainties involved with making a decision, suggesting that when both decision stakes and system uncertainty are high 'post-normal' science is required. This concept, developed by Funtowicz and Ravetz (1993) suggests that these uncertain problems with significant potential consequences, are not answerable or solvable by science or technical experts alone, but that decision processes need an 'extended peer community', comprised of those that are stakeholders in the issue, to establish the validity, quality, or appropriateness of inputs into decisions. This extended peer community may include citizens.

Funtowicz and Ravetz (1993) join many scholars in suggesting that a new form of science is required to meet many of society's problems. Alan Irwin in his influential book 'Citizen Science' (Irwin 1995) describes a kind of science that is able to deal with the many environmental threats that our society faces. He suggests that 'Citizen Science' could be considered to be a combination of: i) science that is done for citizens, addressing their needs and concerns, and ii) science that is developed and enacted by citizens themselves. Others similarly argue that contextual knowledge developed outside of formal scientific institutions by citizens is of considerable value, and that citizens themselves are not 'irrational' or 'ignorant' (Hoffmann-Riem and Wynne 2002). As will be discussed later, what *citizen science* means now in popular culture and its own rapidly expanding literature, is different to some of Irwin's views, which describe a far broader citizen engagement in science as a process (Irwin 1995).

Irwin stresses that the objective of citizen participation in science as a process isn't to erode the value and contributions of science and scientists in society. He is also cognisant of the challenge of integrating differing viewpoints and knowledge into a discussion or decision making process, but points to a need for citizen input and shaping of decisions in order to get effective and fair outcomes (in agreement with many others, e.g. Arnstein 1969; Funtowicz and Ravetz 1993; Renn and Webler 1995; Chilvers 2008; Aitsi-Selmi et al. 2015).

These different rationales for participation help to construct theoretical frames for the problems to which participation might be a solution. Whilst this thesis is focused on citizen involvement with or in science for DRR, insight can be gained from understanding the ways in which the roles of citizens in decision-making processes are understood. One of the most widely used conceptualisations of the ways that citizens might participate in various processes that involve some form of decision making is Arnstein's *ladder of citizen participation* (Arnstein 1969). Arnstein focuses on the power afforded to citizens by different forms of participation in decision making, describing degrees of citizen control over the decisions being made in terms of stages on a ladder, which progress from 'non-participation' through 'degrees of tokenism' to 'degrees of citizen control' (Figure 2-2).

Stirling (1998) also argues for increasing citizen input and control, disagreeing with predominantly technocratic ways of managing risk, describing risk as 'at a turning point', claiming that there is an increasing recognition of the subjectivity of technocratic methods, advocating for both substantive and normative rationales for participation by saying that *'public participation is as much matter of analytical rigour as it is of political legitimacy'.* Stirling and others (Stirling 1998; Stirling 2007; Stirling and Scoones 2009) go further than the post-normal science argument and suggest that methodological flaws in risk assessment and the framing of what risk is, means that decision making requires the participation of all affected parties (Wynne 2005), and that decision making processes about risk need to be opened up by expanding the framing of risk and by involving all affected stakeholders. He argues that in order to 'get the numbers right' (as described by Fischhoff 1995) that citizens need to be involved in risk issues, from problem definition through to data collection and analysis. Furthermore, they should also be involved in decision making, communication, and action to ensure that decisions are less susceptible to framing problems (Stirling 2007). This is in agreement with arguments put forward by Irwin (1995), that citizens are not ignorant but rather science should be done with, by, and for them (e.g. Stern and Fineberg 1996). There is a growing body of evidence that decisions made in this way lead to better solutions (Burgess and Chilvers 2006; Chilvers 2008; Stirling and

Scoones 2009), such as those concerning the management of natural resources (e.g. Lawrence et al. 2006).

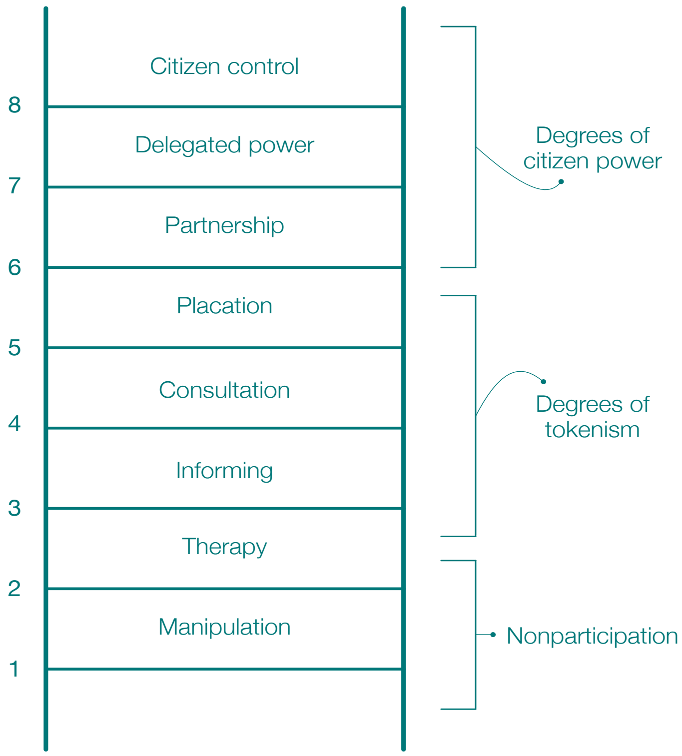


**Figure 2-2 - Arnstein's ladder of participation, reproduced from Arnstein (1969)**

## 2.6 Perspectives from Citizen Science and crowdsourcing

On the fringes of activities that are labelled as participation in science and society or participatory DRR are those that are called ‘citizen science’ or ‘crowdsourcing’. The participatory monitoring described in this thesis often matches well with activities described as citizen science elsewhere (e.g. Conrad and Hilchey 2011). Citizen science and crowdsourcing will be discussed in the same section, and although strictly speaking - according to some (e.g. Haklay 2013) - they differ in a fundamental way (as will be described later), in practice the uses of the two terms are often synonymous. *Citizen science,* popularised by Irwin (1995), has grown to be a discipline of its own, with a meaning that is narrower than originally described, where in most cases it describes a citizens’ involvement in scientific projects or investigations. Much of the academic literature on citizen science comes from fields related to bio-diversity (Conrad and Hilchey 2011) where it often describes an out-sourced or distributed investigative effort style of approach to research, where citizens are able to collect information, either at a scale or in a location, that scientists are unable or un-resourced to do. Citizen science relies on the enthusiasm of citizens to participate (2012), often motivated by the thrill of discovery, concern about a particular issue, or by altruism or curiosity (Conrad and Hilchey 2011; 2012; Gura 2013).

Citizen science initiatives, have led to significant research breakthroughs in diverse fields, such as bio-medicine (e.g. Foldit (Cooper et al. 2010; Khatib et al. 2011)), biodiversity (e.g. Zooniverse (Bonney et al. 2014)) and astronomy (Christian et al. 2012). Citizen science projects have also developed and transformed mapping through participatory geographical information systems (PGIS) (Chambers 2006a; Peters-Guarin et al. 2012; Tweddle et al. 2012; Haklay 2013), and citizen science that is linked to robust scientific standards has the potential to influence policy (Ottinger 2010).

Crowd-sourcing, situated within the field of citizen science, describes a form of citizen participation where data are collected from a large number of people, often dispersed geographically. In practice it varies according to whether or not the information is volunteered or given by the participants, or just harvested from freely/publically available data (i.e. social media, photo sharing websites, etc.). This in effect distinguishes between citizens that knowingly participate and those that do not. It could be argued that non-volunteered (harvested) information is not a form of participation at all, although many scholars insist that it still is (Haklay 2013), and some suggest that all publically posted information about an event is volunteered data (Goodchild 2007; Poser and Dransch 2010; Merrick and Duffy 2013). This line of reasoning is interesting as it implies that willingness or cognisance of participation is not necessarily a barrier for an initiative to be labelled as ‘participatory’. With specific reference to examples from DRR or responses to humanitarian crises, the online USHAHIDI platform (the Swahili word for witness) provides a fascinating example of a mix of volunteered and harvested crowd-sourced information that is combined and used to reduce the impact of various crises (Shanley et al. 2013). Taking a recent example from the earthquake in Nepal (April 2015): the USHAHIDI (quakemap) website displays data that were volunteered specifically for search and rescue purposes and data harvested from social media or photo-sharing websites. This merge of forms of citizen-derived data is common through other uses of the platform (Shanley et al. 2013; Allen 2014).

A keyword search for 'citizen science' and 'DRR' or 'disaster response' returns far fewer results than the different forms of participatory DRR already listed above, although in terms of the roles that citizens play in the participatory process, citizen science has many similarities to other approaches. The lack of adoption of citizen science as a phrase to describe the act of citizens participating in the process of science in the DRR academic literature is interesting. One possible explanation for this is that, just like the myriad of terms used to describe community-based activities that assess or plan for and respond to disaster risk, a lack of connectivity or willingness to adopt another term for participation is hardly surprising. Another explanation may be drawn from the strongly normative rationales for participation in development and DRR as evident by frameworks derived to understand them. This will be discussed further below.

## 2.7 Conceptual frameworks to understand participation and community-based monitoring

With so many different names, processes, and acronyms, it is a significant challenge to understand participatory DRR and the outcomes that it may have. To attempt to do this, it is necessary to look beyond rhetoric or nomenclature and examine the processes themselves. Some of the conceptual frameworks that will be considered in this section are specific to DRR, others are for general participation, or participation in other fields. This thesis does not intend to evaluate any participatory processes or evaluate the outcomes of them, but rather to provide detailed and contextually grounded descriptions of them so that the potential roles of citizens within them can be understood. Some of the frameworks are focussed on participation as a vehicle for citizens to have increasing control over the decision making processes that affect their lives, other frameworks focus on the role of citizens in producing knowledge that informs those decisions.

An instructive framework for both practitioners involved in participatory processes and the researchers of those processes can be drawn from the work of Robert Chambers, and PRA approaches from international development. Chambers (2006a; 2006b)) suggests a series of 'who and whose' questions that can be asked of a participatory process, challenging those involved to consider how the process is or could be constructed, and who benefits from the outcomes. Some of these reflective questions are summarised below (Chambers 2006b):

> *'Whose reality?*
> *Whose knowledge?*
> *Whose appraisal?*
> *Whose analysis?*
> *Whose planning?*
> *Whose action?*
> *Whose M(onitoring) and E(valuation)?*
> *Whose indicators?*
> *Who participates in whose project?'*

Chambers (2006b) notes that in one example, i.e. the work of Rambaldi et al. (2006) in participatory GIS, there are 42 who and whose questions. Chambers then suggests a further question: 'Who determines the 'who' questions?', implying that to truly be people centred, this determination should not perhaps be made by the experts, but by the participants. Many scholars encourage reflectivity around participation, and 'who' questions encourage an adoption of this form of thinking and learning. The rationale behind asking many of the questions is to challenge the knowledge and power interests of all stakeholders in the process. Indeed, many of the rationales for participation that were described earlier focus on power, knowledge, and actions, with the aim of making the ways that decisions are made, and the outcomes of them more equitable.

### 2.7.1 Participation and power

There are many different ways to conceptualise 'power', in terms of what it is and what functions it holds in society (e.g. Lukes 2005; Gaventa 2006). Power is most simply described as what enables an individual to do something that directs or influences the consequences for, or the actions of others. Arnstein (1969) and Habermas (1984), describe decision making power as being in the hands of a few, which can be re-distributed through democratic representation or participation. However, some view power in the way that Foucault describes it (Rabinow 1991), as pervasive through everything, rather than being concentrated in certain areas, and embodied within agents rather than enacted or wielded by them. This means that participatory processes are shaped by power and also have the potential to transform it. There is still some disagreement on how power should be framed or understood (Gaventa 2006), but few doubt the important influence of power on participatory processes (Cornwall 2000; Kothari 2001; Vermeulen 2005). Many suggest that power can be understood in three forms: visible, hidden, and invisible (Lukes 2005). Visible power is where someone more powerful makes someone do something whether they want to or not, whereas hidden power is where the powerful restrict the opportunities of the less powerful to participate in decisions made concerning their lives. Invisible power is experienced by those, who are simply unaware or unquestioning of someone exerting power over them as a result of the adoption of norms or ideologies that keep them powerless.

The different forms of power may be expressed in four ways (VeneKlasen and Miller 2002); *power over*, *power with*, *power to* and *power within*. *Power over* is perhaps the commonly held view of power, involving someone taking power from others and using it for their own gain, by controlling, dominating or preventing others from having it. *Power with* describes individuals who form a collective by identifying common grounds, based on trust-based relationships, collective effort and mutual support, enabling the collective to do more than an individual. *Power to* describes how each individual can have the potential to make choices that can shape her or his life. *Power within* describes an individual's ability to be aware of power, but to be hopeful of a more equitable future and able to imagine or see the steps necessary to build that future. Power within builds, or can be described by, self worth. Power with and power to describe both collective and individual agency. Conceptualising power in these four forms gives insight into the factors that might change as a result of participation, how 'empowerment' may occur, and what roles citizens are likely to desire or be allowed to play.

Again, the widespread adoption of participatory approaches in international development, many of them rooted historically in PRA, provide useful insights into understanding participation. Chamber's (1994) initial rationales for PRA were two-fold; i) that according to evidence, local knowledge was as good if not better than expert knowledge (largely due to contextual understanding), ii) that empowering local communities to assess their own development issues could lead to broader social change and poverty reduction. In many books or articles about participation in development, the role of local knowledge is often overshadowed by notions of power and empowerment, with suggestions that participation can create a new type of citizenship and radically transform the structural factors that are keeping people in poverty (Hickey and Mohan 2004). The push for power and empowerment as a result of participation in development is perhaps best described by the backlash against it. Many of the critiques of participation focus on its abject failure to result in empowerment in many cases (e.g. (Cornwall 2000) and the potential for it to be misused or manipulated, with some suggesting that it is a new form of tyranny (Kothari 2001) or an ideological 'act of faith' (Cleaver 2001).

As a way to explain power, some authors refer to ‘uppers’ and ‘lowers’, where an upper is a person who is more powerful than a lower (e.g. Chambers 2006b). Some advocates of participation suggest that transforming the power of lowers, requires a reduction in the power of an upper (Cornwall 2000), a situation described as ‘zero-sum’ by Chambers (2006b). Chambers suggests however, that empowerment can be ‘win-win’ rather than ‘zero-sum’, where an upper (e.g. a scientist) uses their power or influence to transform the power of a lower, often through the production, sharing and exchange of knowledge. This win-win argument is particularly key for participatory monitoring, where both the scientists and the citizens have something to gain, even if scientists remain as the drivers of the initiative, or as the owners or users of the data. Therefore, empowering local citizens does not have to come at the cost of de-valuing the influence or importance of the roles of scientists in informing decision making about risk.

Power, or a potential lack of it for a citizen, is particularly important under conditions where those who are more powerful make decisions or take actions that lead to an increase in the vulnerability of those who are less powerful. Sometimes the state or municipal authorities take these decisions, but they are also often made at a community or even household level, with factors such as gender or disability inequalities in many cases exacerbating risk (Twigg 2004; UNISDR 2005). Arnstein’s ladder describes the distribution of power in decision making in terms of citizens’ control over the processes (Figure 2-2), providing a useful means for understanding different extents of participation, using the frame of power. It arguably works for many potential cases in DRR, however it is primarily focussed on more deliberative participatory processes, rather than knowledge production or participation in science as a process. Power is thus a very important analytical frame for understanding participation in DRR. It is a dominant driver for and against participation, and forms the basis of many theoretical frameworks for understanding how, where, when and why people are able to participate in risk reduction.

In a valuable and critically reflective research paper on academics using participatory approaches for research and DRR facilitation, Le De et al. (2014) develop a conceptual framework and suggest that from the literature, there are three key principles of participation:

> *'a) Empowering the powerless*
> *b) Instigating changes at policy level*
> *c) Generating sustainable solutions that match with local communities' needs.'*

As is common with other frameworks for understanding or evaluating participatory processes in DRR, these first two principles are again based on power. As discussed previously, many of factors that lead to enhanced risk are the same factors that lead to inequality and poverty (Cannon et al. 2003; Kelman and Mather 2008; UNISDR 2015b), of which power or a lack of empowerment is of critical importance. However, outlining the key principles of DRR as they are above might suggest that participatory approaches, which are not targeted at the powerless, that don't instigate change at policy level or don't generate change at a community level, are less worthwhile. The danger is that participatory DRR initiatives, which are for the purposes of research to better understand hazards, or for the purposes of early warning, are not meeting these key principles, and will potentially be described as such, which may downplay their potential DRR value. Some of the participatory monitoring initiatives described in Chapter 3 are not likely to empower citizens to make choices for themselves, indeed as will be discussed, some of them lead to restrictions of freedoms, as is the case with evacuations based on scientific data about a volcano. Similarly, as is described in Chapter 4, approaches, which are not focussed on empowerment, but are instead based on knowledge production, may lead to empowerment later or in a subtler way. This nuanced empowerment will be discussed in more detail in Chapter 3; volcanoes can be monitored in such a way that the risk around them can be reduced by timely evacuations, which is different to other hazards such as earthquakes, which are less spatially constrained and temporally forecastable. The monitoring means that the state will look for and often pay for scientific monitoring and advice, so the ways in which communities can participate or may be empowered to carry out or benefit from risk reduction may be more nuanced.

The third principle set out by Le De et al. (2014) focuses on communities finding solutions to disaster risk that match with their needs. Identifying and addressing those needs is often facilitated by processes that could be classed as PDRA, which as described in 2.4.2 and below, is a process designed to allow communities to identify and asses risks, producing knowledge that can inform actions to reduce or manage risks.

### 2.7.2 Pelling's conceptual framework (from the development and DRR perspective)

Pelling (2007) sets out a conceptual framework for locating the different approaches to and implementation of PDRA. As will be argued below, the framework may readily be applied to many other forms of participatory DRR where an assessment is needed, data are collected, or citizens collaborate with external experts. A framework that focuses on PDRA is particularly relevant when seeking ways to understand participatory monitoring, as it involves knowledge production in the form of assessment, and often forms of monitoring as well. Part of Pelling's rationale for writing the paper and creating the framework is that it is difficult to avoid misuse or misinterpretation of 'participation' unless we have easier ways to describe or scrutinise it. Noting that participation is a slippery and contested term, he suggests that by adopting a conceptual framework, practitioners, researchers, citizens and other stakeholders can have far less conceptual fuzziness about what participation is, what it does and who wins or loses. Pelling proposes a framework that consists of three continuums (Figure 2-3) to situate different approaches within the broad field of PDRA, so that they can be understood. These continuums are *procedural, methodological and ideological*.

PDRA may vary procedurally, both in terms of its initiation, but also in terms of who drives it or owns its results. It can range from PDRA whereby the participants may initiate the process with technical experts providing technical expertise alone and where the participants use the data for themselves, to a process that is initiated and driven by technical experts, who are either studying the participants or taking the data elsewhere for use.

The methodological continuum describes the different forms of data that might be generated by the approaches, which arguably can be considered relevant to other forms of participatory DRR. Pelling suggests that technical expert driven processes are more likely to generate quantitative data than those driven by the participants. He posits that the wider literature suggests that qualitative data are not only easier contributions for participants to make than quantitative data, but also more familiar to those with no formal science education; therefore, potentially have more meaning to the participants. Pelling refers to claims that whilst it is simpler to generalise or scale up quantitative data, it is also easier for participants to own qualitative data. In response to this, he suggests that such absolute statements should be questioned, preferring to describe them via a continuum rather than distinct and separate modalities.

The ideological continuum describes the motivation behind doing PDRA. It describes how those involved may at one end of the continuum want to empower citizens to assess and manage risk for themselves, and at the other end participation only occurs because technical experts who normally assess risk recognise that citizens are able to contribute important data or analysis that are otherwise difficult for the experts to obtain or perform. Pelling (2007) describes that the former is often labelled as emancipatory, and the latter as extractive.

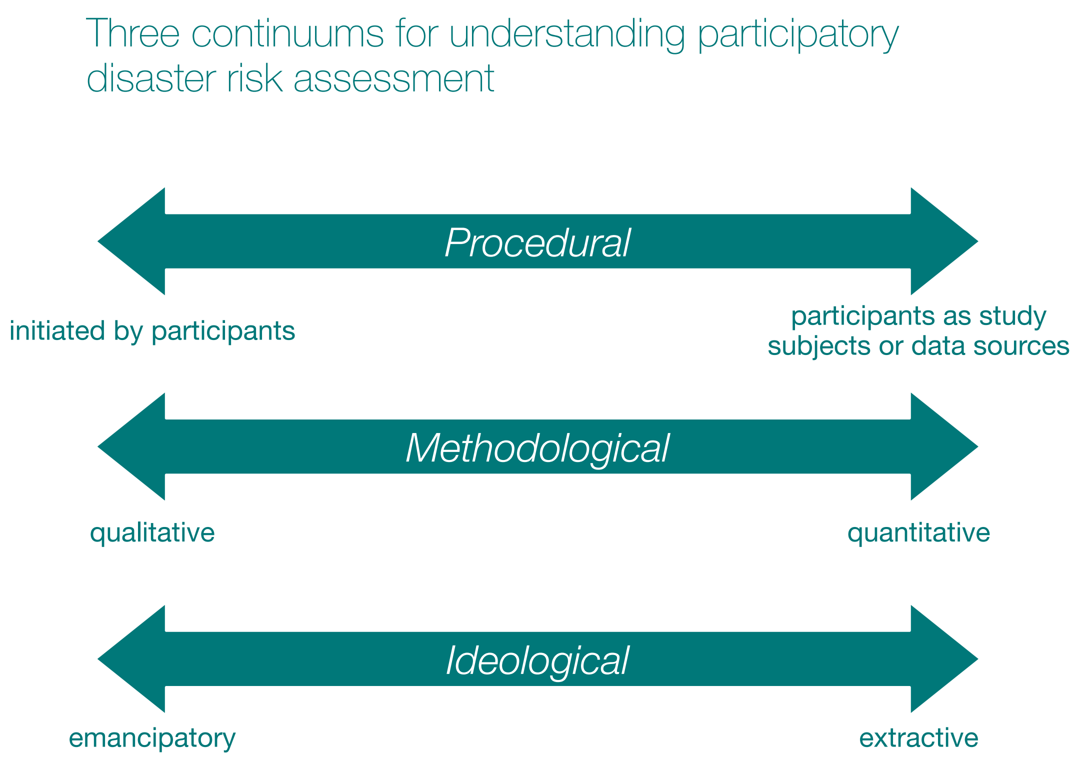


**Figure 2-3 - Pelling's (2007) framework for understanding PDRA**

Pelling's framework, and his description of the variations between PDRA approaches have a pervasive factor in common – power. The ideological continuum is explicitly about power, where emancipatory processes are described as:

> *"normally long-term and iterative and as a mechanism for participants' self-reflection, consciencisation (Freire 1981), and self-empowerment, with the potential to catalyse change in the social or material structures of life that influence the distribution of vulnerability. This is given higher priority than the generation of data for its own sake" (Pelling 2007) p.376.*

This is then contrasted against extractive approaches that are primarily concerned with data collection and could be used in quite an instrumental way by experts or authorities. The procedural continuum, in turn, describes *'the relative distribution of power and ownership in the assessment process'* (Pelling 2007) p.375. Finally, even the methodological continuum is in part shaped by power, in that quantitative approaches are said to be more easily controlled by technical experts (e.g. Le De et al. 2014).

Pelling's framework is very useful in a number of ways, as it attempts to makes sense out of different initiatives and provides conceptual parameters with which to describe the variations. Although Pelling makes no attempt to do so, there are however, a number of problems with the framework if it were to be applied to participatory DRR more generally and some more specific issues that might arise if it were to be applied to community-based monitoring. The ideological dimension of the framework inevitably puts 'extractive' at the opposite end of the continuum to emancipatory. Given the strongly normative, and persuasive, arguments for participation in development as described previously, this could lead to some participatory monitoring approaches being described as extractive, simply because they are not designed to be empowering. The labels emancipatory and extractive are perhaps not entirely value neutral, as a result of normative arguments for participation and criticisms of it, such that extractive may appear synonymous with exploitative.

Pelling discusses at some length the acceptability of PDRA that does not aim to empower those involved, and goes further than many normative discourses to acknowledge the merit of outsider driven, forms of participation, which feature and have a primary purpose of producing knowledge that protects physically vulnerable populations and saves lives. He further questions notions of total participation or empowerment in even the most emancipatory PDRA initiative, by suggesting that in practice, citizens are rarely involved in all stages of the process, as outlined below:

- Initiating the assessment
- Identifying what is at risk
- Identifying sources of hazard, vulnerability or capacity
- Designing assessment methods
- Collecting data

- Analysing data
- Drawing conclusions for action
- Acting on results; and
- Reviewing the usefulness of the assessment

These different stages point to the different roles that citizens have to play in PDRA processes. The activities in some of the stages are similar to the processes involved in participatory monitoring. However, the theoretical construction of a continuum that places extractive characteristics in opposition to emancipatory characteristics could force an evaluation of an initiative using this framework to be biased towards elevating normative rationales for participation above others, rightly or wrongly. This is unavoidable unless there is a recognition that occupying an end member on the continuum need not necessarily represent a DRR process that is flawed.

Power is a legitimate analytical concept to apply to participation, and one that Pelling draws out from the literature. However normative rationales for and criticisms of participation can in some cases make it difficult for many of the examples of initiatives like crowdsourcing (volunteered or not), citizen science or participatory monitoring to be described or contextually grounded in a value neutral way using the ideological continuum as a means to evaluate an initiative. However, as a whole, Pelling's continuums provide a very useful analytical framework that could be applied to understanding the roles of citizens in DRR, and for understanding the roles of citizens in participatory monitoring around volcanoes. It also aids with identifying what characteristics drive effective DRR in practice. Indeed, the methodological and procedural continuums are very useful for this. It is only the ideological continuum that poses potential problems, because of the strongly normative association of participation within development.

A conceptual framework about PDRA is particularly helpful for understanding participatory monitoring, as PDRA is ostensibly about knowledge production.

The knowledge produced is about hazards that may affect an area and the ways in which people may be vulnerable to them. This knowledge can then be used to inform actions that can reduce risk. This reduction in risk as a result of the knowledge production, is also empowering for citizens, even if the participatory process itself only fulfilled one of the ideals suggested by Le De et. al. (2014).

### 2.7.3 Haklay's levels (from citizen science)

It could be argued that understanding participatory monitoring requires a conceptual lens that is focussed more on knowledge production than on power, and Haklay (2013) does this by describing citizen participation in knowledge production in the context of citizen science for volunteered geographic information. He does this by describing four levels of citizen science (Figure 2-4). In doing so, Haklay refers to other frameworks, such as Arnstein's ladder (Figure 2-2), but notes that there are differences between citizen science and some other participatory processes. Haklay's levels of citizen science are not explicitly framed in terms of empowerment or power, stating that *'there shouldn't be a strong value judgement on the position that a specific project takes'*. Haklay simply acknowledges the potential role of participation in empowering citizens or re-balancing power dynamics in some cases. However, when the data collected by citizen scientists are associated with issues that have an impact on people's lives and livelihoods, it can be argued that the knowledge produced and how it is used, does implicitly affect the power of participants and other citizens. When considered in this way, Haklay's levels imitate the rungs in Arnstein's ladder, effectively describing levels of citizen empowerment without using the language of power.

The four levels in Haklay's framework refer to the participants being increasingly involved in the process of science; defining problems, designing data collection, analysis, interpretation and synthesising learning.

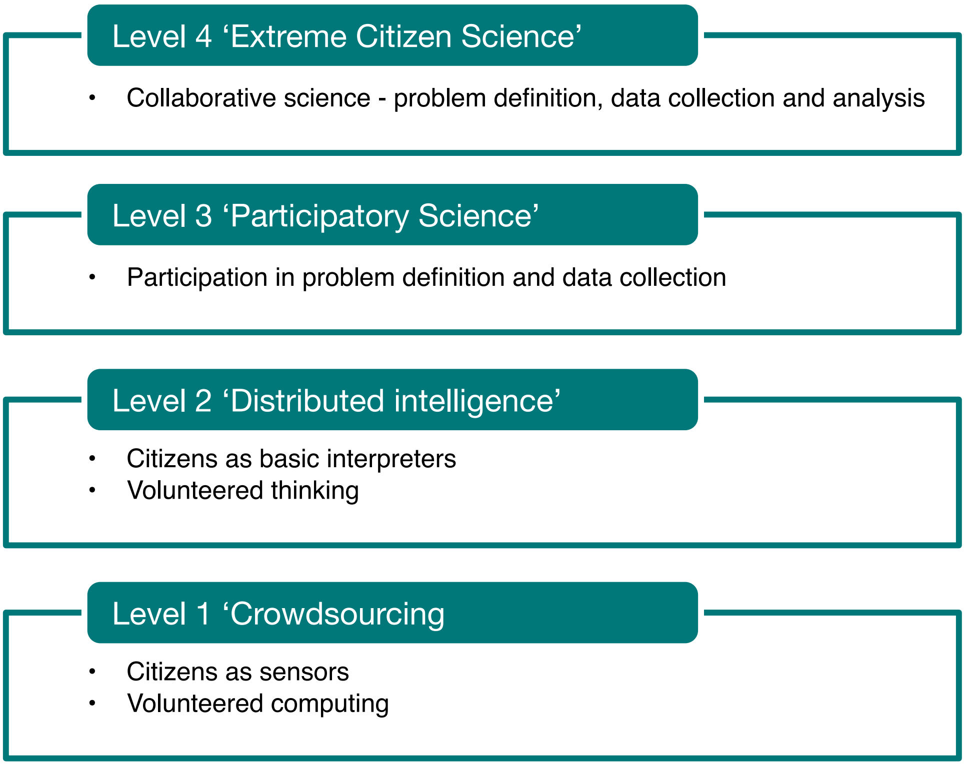


**Figure 2-4 - Levels of participation and engagement in Citizen Science projects (reproduced from Haklay et. al. 2013)**

Level 1 'Crowdsourcing' describes activities where citizens contribute data collected through sensors, that they carry around (i.e. a smartphone) or through distributed computing (e.g. Christian et al. 2012). Level 1 is characterised by citizens willingly participating, but by them not cognitively engaging in the data collection, beyond downloading an app or some software. Haklay and others (e.g. Goodchild 2007) describe this as participation, but it clearly requires the most limited involvement on behalf of the participants. There are some notable examples of crowdsourcing of this kind in DRR, for example 'Quake-Catcher' (Cochran et al. 2009), which uses distributed computing and software to detect strong motion following earthquakes by accessing data from computers' accelerometers.

Haklay's definition of what forms of crowdsourcing are classified at level 1, based on citizen science within the context of volunteered geographical information, is whether or not citizens have knowingly made a decision to participate. His framework does not therefore cover crowdsourcing in the way that USHAHIDI uses the crowd, where information is rarely volunteered directly by citizens for the purposes that it is then used for, but rather is predominantly extracted from publically available data such as social media (Shanley et al. 2013).

Level 2 describes citizens volunteering their cognitive ability to the process of science, in what Haklay describes as ‘distributed intelligence’. Most citizen science projects operate at this level, such as the Royal Society of the Protection of Birds’ ‘Big Garden Bird Watch’ (2012) or many of those projects described in Conrad et. al. (2011). Often citizens will receive some form of training, or feedback on the data that they submit. The data collection may involve some form of interpretation, but they are unlikely to perform significant analysis of the data collected.

Level 3 describes an extent of citizen participation, whereby the participants are involved in defining what question they want to answer, and normally collaborate with scientists and experts to develop or decide upon data collection methods. They also may often require external help from scientists to analyse the data and interpret results. Haklay likens this to ‘community science’ and suggests that it has strong parallels with Irwin’s (1995) notions of science done for and with citizens. Level 3 is common in areas such as environmental justice, perhaps typified by the ‘Bucket Brigade’ (Ottinger 2010), where citizens who were concerned about air quality contacted scientists so that they could devise a way to monitor air quality and have it analysed by experts (Ottinger 2010; Conrad and Hilchey 2011).

At Level 4 the whole process is integrated, so that participants choose their level of involvement and scientists act as both facilitators and experts. The description of Level 4 and the distinction between it and Level 3 is less clear than with the other levels. Haklay describes Level 4 as ‘extreme citizen science’, suggesting that it puts scientists on a completely equal footing with participants, and in fact requires scientists to become citizen scientists themselves in the ways described by Irwin (1995); in less colourful terms it might be described in as ‘collaborative science’.

Haklay also suggests that within a single project, citizens can participate at different levels, such that different citizens can have separate roles within the same project. The stratification of participation is a very useful facet of Haklay’s framework, and echoes Pelling’s (2007) observation that although PDRA has many different stages, participants are unlikely to participate in all of them.

## 2.8 Synthesis and analytical framework

All of the conceptual frameworks discussed so far are helpful for understanding and describing some of the roles of citizens in DRR, particularly those roles that lead to or signify empowerment. What becomes more challenging, however, is applying many of the existing frameworks to unpick understanding of the full spectrum of roles that citizens might play for DRR when initiatives are more focussed on knowledge production, as could be argued is the case with community-based monitoring.

It is known that knowledge about physical hazards and the monitoring of them enables many risk reducing actions to be taken (Aitsi-Selmi et al. 2015), however, many people are at risk because of entrenched or unknown vulnerabilities, which arise not just because of a lack of knowledge about physical hazards, but as a result of a lack of power and subsequent inequalities. Reducing risk therefore, requires the needs of the most vulnerable to be represented and accounted for – hence the drive for participation in development and DRR. Thus when examining the roles of citizens in DRR and more specifically in participatory monitoring, there is an intellectual struggle between using the conceptual lens of power, which is pervasive and fundamentally shapes the roles of citizens, and the lens of knowledge; how it is produced, communicated and acted on to reduce risk.

Many of the frameworks discussed in this chapter reflect the fundamental importance of power in shaping the ways, including the spaces and scales of processes, in which citizens may participate (Gaventa 2006), however they focus more on empowerment and social change, than knowledge production. Whereas, Haklay's framework and its primary focus on knowledge production and use, which is well suited to understanding the risk reducing effects of knowledge derived from participatory monitoring, is arguably less applicable for understanding how and when citizens may, as a result of the process, do more than produce knowledge and take actions to reduce risk for the community. It is possible to apply the conceptual lens of power to Haklay's framework, where the increasing involvement of citizens means that they eventually gain an equal footing with scientists in the production and ownership of knowledge. However, Haklay's framework suggests that simply acknowledging interests and power does not require the analyst to adopt a normative stance, as many in the DRR context do.

Both Haklay and Pelling suggest that citizens are motivated to be involved in knowledge production, irrespective of whether or not it is empowering. This point is reinforced by evidence that citizens are motivated to participate in a great range of citizen science projects, from the minimal or short-term engagement of many crowdsourcing activities through to the longer-term commitment and responsibility associated with community-based monitoring (Conrad and Hilchey 2011). As is evident, citizens may potentially benefit considerably from participation that is effective and equitable.

Haklay's framework, and the theories associated with citizen science, has considerable potential if applied to citizen participation in knowledge production for disaster risk reduction. The primary focus on knowledge production, rather than power, potentially avoids implicitly value based descriptions of initiatives, that could in a negative way be described as scientist-led, quantitative and possibly extractive by those using Pelling's framework (2007) or fall short of attaining many of the principles of participatory DRR as suggested by Le De and others (2014). However, if an analyst were to use the power based frameworks, where the knowledge production was for DRR rather than solely for academic science or research, then any accusation of it being extractive or exploitative would always be contestable, even if the local citizens were far from being equal partners in the research process.

Haklay's framework gives an opportunity for those initiatives that would appear to be more extractive (using the other frameworks) to be set within the context of initiatives that are more empowering or do have greater citizen involvement, without implicitly devaluing them on normative grounds. It also suggests how, in a ladder form that is drawn from the work of Arnstein (1969), citizens may progress from scientific sensors to equal partners. However, the predominant focus on knowledge production in Haklay's framework does not acknowledge the other ways, beyond knowledge production, in which citizens can participate in DRR making use of individual and collective agency. If applied to a community-based early warning system (as described in Chapter 4), for example, Haklay's framework would facilitate a description of the monitoring that citizens do, but might not extend to the interrelated activities through which they communicate early warning, foster trust-based relationships and learning, or facilitate risk management planning and evacuations, although many of these benefits are known to arise from citizen science (Conrad and Hilchey 2011). The potential for these added roles and benefits as a result of being participatory monitoring will be discussed in more depth in Chapters 3 and 4.

The evidence discussed so far clearly suggests that empowering communities can enhance risk reduction, and that this is both normatively, instrumentally and substantively justified. The question then, is not whether empowerment as a result of participation is or is not desirable, but rather doubt is cast over whether or not ‘power’ should be used as the primary conceptual frame for understanding participatory monitoring, across multiple scales and contexts. The danger is that taking power as the dominant conceptual frame for understanding or describing participatory monitoring may lead to other important factors related to knowledge production that may contribute to or inhibit risk reduction to be overlooked. However, ignoring the dynamics of power in participation risks widening inequality and deepening vulnerability and therefore not reducing risk at all.

The pervasive importance of power, creates a compelling argument for conceptual frameworks to focus on it. However, it is clear that a balance needs to be struck, as a dominant focus on power potentially undervalues the impacts of initiatives such as citizen science, or crowdsourcing for DRR. Taking crowdsourcing as an illustration, i.e. the use of USHAHIDI, where the citizens are often not even voluntarily participating: the data are quantified, collected by scientists in an ostensibly extractive manner, and the results are used by authorities or responding agencies. So it could be argued that this would not be considered ‘participatory’ if the frameworks suggested by Pelling (2007) and Arnstein (1969) or principles suggested by Le De and others (2014) were to be applied to it. If an example like USHAHIDI is participation, it may be considered the ‘worst’ or ‘least best’ form if understood using those frameworks, yet, forms of participation like this have had considerable risk reducing effects (Goodchild and Glennon 2010).

If there were no connotations surrounding the term *extractive*, and it was not placed at the opposite end of a continuum to *emancipatory,* then Pelling’s (2007) framework for understanding PDRA would enable a full and detailed understanding to be built about participatory monitoring initiatives. However, the normative implications surrounding the ideological dimension are problematic for the reasons suggested above. As Pelling discusses at length, there is considerable merit for PDRA even if it has no aims to be empowering, stating that knowledge production alone is valuable. However much of the literature about participation in DRR or development questions or criticises approaches that are not directly empowering. This is contrasted against Haklay's framework that acknowledges power, but arguably de-emphasises it too much when applying the framework to contexts that are risk-based as opposed to science discovery contexts, where empowerment or a lack of it are less likely to affect the ways in which the knowledge is used.

Therefore, it is clear that power can not and should not be ignored, but focussing on it should not come at the cost of understanding the role of knowledge, particularly for activities like community-based monitoring which are predominantly focussed on knowledge production. Thus using Pelling's framework, but placing less emphasis on the *ideological continuum,* and combining it with the sharper knowledge production and citizen science lens provided by Haklay's framework would enable a conceptual understanding that is aware of the ways in which power influences participation and risk reduction, but with a predominant focus on knowledge production. All of the frameworks have strengths and weaknesses, therefore viewing a participatory monitoring initiative through the lenses of different frameworks is perhaps a pragmatic and instructive way forward.

This chapter develops an argument that discusses the relationship between knowledge production and power, in developing analytical frameworks that can be used to understand the value or efficacy of participatory monitoring. From the perspective of international development, from which DRR is arguably derived, the dynamics of power in participatory processes are considered central to any understanding of their potential outcomes (e.g. Chambers 1994; Kothari 2001; Hickey and Mohan 2004; Le De et al. 2014). Others discuss the value of knowledge produced by citizens (e.g. Pelling 2007; Conrad and Hilchey 2011) and the important role of scientific knowledge when making adaptations to reduce disaster risk (Gaillard and Mercer 2013; Aitsi-Selmi et al. 2015).

The conceptual framework developed here takes a pragmatic view of the disconnect between participatory DRR and citizen science, by drawing on two frameworks: i) Pelling's (2007) framework for PDRA, which focuses both on the initiation of participation, the nature of the data collected, and whether it is extractive or empowering for citizens involved in the process; and ii) Haklay's (2013) framework which describes levels of citizen science, where citizens become increasingly involved with designing the study, interpreting data, and ultimately producing knowledge.

The two frameworks focus on the role of knowledge, one for advancing scientific understanding, the other for enabling risk reducing adaptations. Pelling's framework explicitly mentions the importance of power in the participatory process: Haklay's more implicitly refers to power, with the levels of citizen science bearing resemblance to work by Arnstein (1969).

Monitoring of volcanoes is a means of producing knowledge about their behaviour with applications both for research and for early warning of their hazards. Citizens that participate in monitoring processes therefore may produce knowledge that is of use for both of these applications. However, the citizens involved in participatory monitoring are often not just involved in the production of knowledge, but they may then communicate it to others, and take risk reducing actions based on the knowledge gained. When conceptualised in this way the potential for a new conceptual framework emerges, where the roles of a citizen become clearer, a participating citizen can be one or a combination of: a knowledge producer, a knowledge communicator, or an agent that makes decisions or actions based on knowledge.

## 2.9 Conclusions

Citizens can play important roles in DRR, reducing the impact of physical hazards by better understanding them and providing appropriate early warning, and by taking actions that reduce vulnerability and exposure. Understanding the roles of citizens in these risk reduction processes and more specifically in participatory monitoring, requires an awareness of the factors that shape the roles that they are able and allowed to have. These factors include the risk governance context, the production of knowledge and early warning systems, the nature of the hazards in question, the agency of the citizens themselves, and the perceived benefits for all stakeholders. Participatory monitoring is an important focus of study, as the processes of disaster risk reduction depend upon knowledge, in terms of it's availability, communication and the actions that can be based on it (Pelling et al. 2004; UNISDR 2005; Pelling 2007; Maskrey 2011). The importance of knowledge for DRR raises questions about from where and from whom that knowledge should come. Many scholars advocate for the strengths and importance of expert derived scientific knowledge for risk reduction (e.g. Sparks et al. 2012), whereas others state the importance of integrating scientific and local or other forms of knowledge (e.g. Pelling 2007; Cronin et al. 2004a; Stirling 2007).

As will be discussed in Chapter 3 and the following chapters, volcanoes and their hazards provide an interesting context for understanding the ways in which expert derived knowledge can be supplemented with, enhanced by, or sometimes proceeded by the knowledge that can be produced by citizens. For example, citizens may collect data at scales or locations that scientists can not (e.g. Stevenson et al. 2013) or produce knowledge for and incorporate it into more formal risk assessments (Cadag and Gaillard 2012). Thus the interfaces between formal and informal, scientific and citizen derived knowledge, in addition to how observations or data lead to the production of knowledge, are important loci of study.

This chapter has identified several analytical frameworks that may be used to understand the roles of citizens in the examples of participatory monitoring that will be investigated in the following chapters. This thesis will use a number of the frameworks, with a particular focus on Pelling's (2007) and Haklay's (2010), to understand the roles of citizens in participatory monitoring of volcanoes. The analysis will draw on a global survey and two case studies from long term volcanic crises. It will focus on knowledge production about hazards and the role of that knowledge in early warning and decision making about risk, and describe how power shapes the ways that citizens are able to participate in this. The different conceptual frameworks will be used to offer contrasting perspectives and ultimately yield a deeper understanding of how participatory monitoring can reduce risk in volcanic areas, with learning that can be applied other hazards.

# Chapter three

# Chapter 3: Participatory monitoring of the world's volcanoes: motivations and outcomes

## 3.1 Introduction

To provide warnings of impending volcanic activity, institutions that monitor volcanoes have a challenging task. The behaviour of volcanoes is inherently uncertain: eruptive activity at the surface is a complex consequence of magmatic composition, flux rate and multiple interacting boundary conditions such as the stress field, surface cover and magma re-supply (Sparks et al. 2012). Tilling (2008) suggests that the most effective way to forecast volcanic impacts in the short term, or through the course of an eruptive episode, is through volcano monitoring. Monitoring volcanoes requires expertise across a number of disciplines, and the transition from collecting to using and interpreting monitoring data requires the capacity to cope with both epistemic (reducible) and aleatory (irreducible) uncertainty (Hicks et al. 2014). Eruptive products cover wide areas, can affect millions of people, and anticipatory adaptations to their multiple hazards are rarely clearly defined due to difficulties in anticipating the timing and magnitude of volcanic impacts (Loughlin et al. 2015).

The provision of early warnings or short-term forecasting of hazards, vital for risk reduction around volcanoes, are also part of the key priorities for several recent international or multi-national strategies concerning DRR more generally (UNISDR 2005; UNISDR 2015a). This is in accord with the statutory or institutional mandates of institutions responsible for volcano monitoring.

These usually include: i) hazard and or risk assessment, and ii) monitoring and some form of communication of monitoring data, forecast or early warning information. Thus, volcano monitoring institutions typically have responsibility for the production and communication of knowledge that is then used to inform decision-making with the goal of reducing risk. In many instances this also involves participation in decision-making around the management of risk (Newhall 1999, WOVO Constitution).

This chapter is focussed on understanding the ways in which citizens participate and collaborate with the activities of these monitoring institutions, principally around the central roles of hazard or risk assessment, and early warning. Therefore, it will mainly focus on citizen involvement in knowledge production, often in the form of monitoring, but in some cases more specifically for research rather than early warning.

Although there are many different words for and forms of participation in disaster risk reduction (see Chapter 2), 'participatory monitoring' is used here to encapsulate activities relevant to volcano monitoring institutions (as a study subject) such as, crowdsourcing, Community-Based Early Warning Systems (CBEWS) and community-based monitoring. These types of activities also usually occur over the same scales and can generate outcomes most comparable to *citizen science* (Chapter 2.6). However, 'participatory monitoring' about phenomena that could negatively affect the participant's wellbeing, livelihoods or lives, is subtly different to many initiatives that would be normally be described as 'citizen science' (Chapter 2.6). In these 'risk contexts', knowledge that the participants help to generate may be used to mitigate negative outcomes on their or their community's lives and livelihoods. Thus, because it will also investigate outcomes and aims that intersect with the different and arguably broader goals of participatory disaster risk reduction, this Chapter, as in Chapter 2, will use the term 'participatory monitoring'. This encompasses the interactions around volcano monitoring between citizens and scientists, or their institutions, which are the focus of this chapter.

Despite the fact that in volcanic environments, involving citizens at risk in participatory monitoring activities has the potential to not only generate new knowledge but to prompt risk reduction adaptations (e.g. Mothes et al. 2015) there is comparatively little analysis of any of these activities to date. To address that lacuna, this chapter provides results and analysis of a global survey of current practice. The research has been designed to provide a first order understanding of how various forms of participatory volcano monitoring fit within the frameworks described and synthesised in Chapter 2.

This chapter will present the results and analysis of a global survey of volcano monitoring institutions to determine the extent to which participatory monitoring forms part of current practice, and to gather evidence for the ways in which it may act as a catalyst for making adaptations to reduce volcanic risk. The scope of this survey and chapter is intentionally focussed on volcano monitoring institutions (VMIs) as they are often at the nexus of early warning, research, risk management and disaster preparedness in volcanic areas, and have not been studied in this way before.

As discussed in chapter 2, VMIs are not the only institutions, organisations or individuals coordinating or collaborating in forms of participatory monitoring or other participatory forms of risk reduction around volcanoes. The majority of participatory DRR initiatives more generally are driven by NGOs working on development or humanitarian projects. Many of these are inevitably in volcanic areas and some of these initiatives do include forms of community-based early warning systems, which rely on active and sustained participation from citizens (e.g. Mercer et al. 2012a) but are often focussed on longer term hydrological volcanic flooding (lahar) hazards. Further participatory initiatives are instigated or run by researchers (e.g. Reid 2009; Cadag and Gaillard 2012; Rymer 2014), often concentrating on risk assessment or enhancing hazard awareness. As described in Chapter 2, very few of these initiatives involve any activities that are comparable to monitoring. This participatory DRR can in many cases just involve citizens and NGOs, and therefore, these processes can be independently carried out without involvement from local volcano-monitoring scientists, often to limited effect, such as those activities described by Bowman and White (2012). Where available in the literature, these initiatives are discussed in this chapter, along with the more structured information elicited from the more technical monitoring institutions.

## 3.2 Volcanoes and the institutions that monitor them

### 3.2.1 Volcanic activity and how it is monitored

Volcanoes have the potential to impact lives and livelihoods over varying spatial and temporal scales, but fortunately due to considerable understanding gained through experience and research in recent times it is often possible to provide some form of early warning of their hazards (Sparks et al. 2012; Sigurdsson et al. 2015; Loughlin et al. 2015). Monitoring of volcanoes is wide ranging in the techniques used (Sparks et al. 2012; Jolly 2015b). Prior to new activity, or the onset of a change in activity, the passage of hot, viscous fluids (typically a mixture of gas or magma with entrained liquids) must involve the fracturing and displacement of the crust through which they move. Thus, geophysical instrumentation, capable of detecting these subsurface processes (usually via the measurement and location of the release of seismic energy or the detection of millimetric changes in surface deformation) is ubiquitous in many observatories (Jolly 2015a). Similarly the detection of changes in gas mass flux at the surface can provide an early indication of changing conditions, so the use of various sensors to detect volcanic gas is widespread (Rouwet et al. 2014). The utility and level of detail (e.g. locational information) becomes greater when more than one instrument is deployed around a volcanic edifice in a network, and the data relayed back to the observatory in real time (e.g. Sparks et al. 2012). Seismic instrumentation is also capable of detecting surface flows (pyroclastic density currents and lahars). Observatory scientists usually map new deposits as they occur; considerable value can be found in almost all settings through detailed geological mapping of both recent, historical and prehistoric deposits allowing scientists to understand past and current eruptive products and infer potential future impacts. Finally, the importance of visual observations, systematic or not, and the visual verification of hazards detected by geophysical networks for making risk management decisions should not be underestimated (Mothes et al. 2015), whether explicitly acknowledged in monitoring programs or not. Increasingly, volcano observatories also have remote cameras trained on the volcanic edifice and telemetered to the observatory, particularly where line of sight is not available (Sennert et al. 2015).

Volcanoes pose a considerable threat to sustainable development (UNISDR 2015b). There are more than 1500 volcanoes considered to be active (Simkin et al. 2001), and whilst there are thought to be over 100 VMIs, many of them monitoring more than one volcano each, the majority of volcanoes are not monitored, with the most active or most recently active taking priority (Jolly 2015a). For example, in Central America, of the 314 volcanoes that have been active in the Holocene, 64% are currently not monitored (Ortiz Guerrero et al. 2015). Limitations or variance in monitoring arise because monitoring networks are difficult to finance and maintain, and thus there is a considerable difference globally between instrumentation at volcanoes; some in more developed countries may have 100s of sensors, whereas many in developing countries are not monitored at all (Jolly 2015b).

### 3.2.2 A case for monitoring volcanoes

A reasonable projection based on estimations made by Auker (2013) is that in the near future it is likely that 1 billion people will live within 100 km of an active volcano. However the number of fatalities caused by volcanoes appears to be in decline (Auker et al. 2013). This can be attributed to one or more of several possible factors: the advent of more sophisticated means to monitor volcanoes; a better understanding of volcanic processes; or perhaps a lack of eruptions either of a significant enough magnitude or proximity to populations to cause large numbers of fatalities, since the eruption of Nevado del Ruiz in 1985 (Voight 1990; Barclay et al. 2008).

Against this backdrop of apparent volcanic risk reduction successes, in terms of economic losses, eruptions have been known to disproportionately affect the development of small island developing states (SIDS) and developing countries, and pose a significant concern to developed high-income countries such as the United Kingdom (UNISDR 2015b), to the extent that volcanic eruptions are twice on the United Kingdom National Risk Register of Civil Emergencies (Cabinet Office 2015), mainly as a result of the uninsured losses from the 2010 Eyjafjallajökull eruption and associated disruption to airspace (Rees et al. 2012).

Losses (lives, livelihoods and assets) from disasters in general are increasing (UNISDR 2015b), as are global inequalities in risk, where the poorest nations and citizens are disproportionately affected by physical hazards. Furthermore, uninsured losses are mounting, and the impact of disasters on the future development of countries regardless of income could be very similar (UNISDR 2015b). As suggested by Ban Ki Moon at the launch of the 2015 Global Assessment Report on DRR: *"Most disasters that could happen have not happened yet",* adding that there is an imperative for *"managing risks rather than managing disasters"* (UNISDR 2015b). Sparks et. al. (2012) state that "*despite technological advances, volcano monitoring around the world is woefully incomplete".*

Therefore the case for monitoring volcanoes is extremely strong; not only has monitoring been shown to reduce risk, but the potential consequences of future eruptions could significantly impact the development of many countries, so continued investment in volcano monitoring is critical (Tilling 2008; Loughlin et al. 2015).

### 3.2.3 The roles and responsibilities of volcano monitoring institutions

There are over 70 members of the World Organisation of Volcano Observatories (WOVO), an organisation that aims to represent volcano observatories internationally; and facilitate collaboration, learning and support. It is run by representatives from volcano observatories, universities and government scientists. The number of members is not a straightforward count of how many countries there are that monitor volcanoes, but reflects the complexity of the systems, in itself a partial reflection of the scales over which volcanic activity can have an impact. In its simplest form a 'volcano observatory' would be a single institution monitoring a single volcano, but some of the WOVO members are Volcanic Ash Advisory Centres (VAACs) and several countries list each observatory as a different member (e.g. Japan with 16) and others just list all observatories as a single institution (e.g. Ecuador). More commonly, institutions may have responsibility for multiple volcanoes within a region (e.g. the Cascades Volcano Observatory, which monitors Mount Sts Helens, Mount Ranier and Mount Hood among others). Volcano observatories can be institutions dedicated to this purpose or contained within another larger organisation such as a wider research institute or national geological survey. In some countries multiple entities have joint responsibility for monitoring different aspects of activity (e.g. Icelandic Meteorological Organisation and the Nordic Volcanological Center). To add further complexity, some aspects of volcanic hazards that are often cross-border are monitored by organisations like the VAACs. For example, volcanogenic tsunamis would be monitored by regional tsunami warning centres. As discussed previously, for the purposes of this chapter, all institutions that have a role in monitoring volcanoes will be called volcano monitoring institutions. The monitoring carried out by these institutions is normally for the purposes of providing information, advice and warnings regarding current and potential activity (Newhall and Hoblitt 2002; Aspinall et al. 2003), with the ultimate aim of risk reduction. Further, as a result of inequality in terms of resourcing, different VMIs have considerable variations in capacity, often requiring support in the form of international cooperation (e.g. the United States Geological Survey, Volcano Disaster Assistance Program team (USGS VDAP)), benefitting increasingly from space-based remote sensing (Biggs et al. 2014), and in many cases, it is citizens living closest to a volcano that first detect unrest or initial eruptions.

New international frameworks for disaster risk reduction (e.g. SFDRR (UNISDR 2015a)) and previous frameworks (UNISDR 2005) reflect a desire to find new ways to frame the importance of institutions like VMIs. The new Sendai Framework for Disaster Risk Reduction (UNISDR 2015a), can be used to interpret the potential roles of volcano monitoring, which have been summarised in Table 3-1. What characterises VMIs as particularly special DRR institutions and worthy of study is that they are often involved in so many DRR processes simultaneously, from monitoring and forecasting, research and early warning (Jolly 2015b) (Table 3-1). Further, they can often be embedded, at least spatially, within 'at risk' communities, which is quite different to most science institutions that issue early warning for other hazards such as the Pacific Tsunami Warning Centre (Bernard et al. 2006).

As a consequence of the organic way in which different organisations have set up in response to local or regional need, there is a large institutional variance in capacity and remit, and no internationally agreed standard for what constitutes a VMI. In different contexts the formal and informal roles of a VMI and its contributions to risk reduction can entail: monitoring, research, enhancing public awareness, hazard assessment, risk communication, decision-making, or policy advocacy (Aspinall et al. 2002; Donovan et al. 2013; Jolly 2015b). Each of these many roles necessitate different responsibilities where the boundaries between them are often poorly defined (Donovan and Oppenheimer 2015). As such, the institutions responsible for monitoring volcanoes use a number of different, and often contrasting methods to facilitate the reduction of risk, but ultimately citizens are a major end-user of the information that these institutions generate (Barclay et al. 2015; Jolly 2015b).

| SFDRR and relevancy for role of VMIs | Implication for VMI | Section (or especially relevant text) |
|---|---|---|
| Guiding principles | *Engage with all of society, empower local authorities and communities to reduce disaster risk, with a multi-hazard approach where decisions are based on up-to-date science-based information* | ***III***<br>*d) all of society engagement and partnership*<br>*f) … it is necessary to empower local authorities and local communities to reduce disaster risk, including through resources, incentives and decision-making responsibilities, as appropriate*<br>*g) Disaster risk reduction requires a multi-hazard approach and inclusive risk-informed decision-making based on … up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge* |
| Priority | | |
| 1) Understanding disaster risk | *• Hazard mapping*<br>*• Risk assessment*<br>*• Research*<br>*• Monitoring*<br>*• Promote/advocate use of volcanic risk knowledge*<br>*• Sharing internationally* | *24: a),b),c),e),f),g),h),i),j),k),m),n),o)*<br>*25:a),b),c),d),e),g),h),i)* |
| 2) Strengthening disaster risk governance to manage disaster risk | *• Coordination role with other institutions in risk management process*<br>*• Advocacy role about volcanic risk reduction* | *26*<br>*28 a), b),c),d),e),f)* |
| 3) Investing in disaster risk reduction for resilience | *• Benefit from funding, or compete for funding*<br>*• Advocate roles of VOs in increasing resilience*<br>*• Advocate use of risk or hazard assessments etc for appropriate planning*<br>*• Engage with special interest groups, i.e. tourism* | *30: f,)g,)q)*<br>*31: c),i)* |
| 4) Enhancing disaster preparedness for effective response and to "Build back better" in recovery, rehabilitation and reconstruction | *• Be involved in informing/preparing/reviewing/updating disaster preparedness and contingency plans*<br>*• Facilitate participation*<br>*• Develop + sustain early warning systems*<br>*• Enhance & disseminate early warning info*<br>*• Promote disaster preparedness*<br>*• Promote cooperation between diverse institutions*<br>*• Strengthen capacity for authorities to evacuate people when necessary*<br>*• Promote development of guides, best practice or protocols* | *32*<br>*33: a), b),d),f),h,)l,),l),m)*<br>*34: b),c),f),g),h)* |
| Monitoring institutions as stakeholders | *• Collaborate with civil society, volunteers …, disadvantaged groups and community-based organisations*<br>*• Do high quality research, support interface between policy and science for decision making*<br>*• Engage with businesses and private sector*<br>*• Engage with the media* | *36: a),b),c),d)* |

**Table 3-1 Showing relevant sections of the Sendai Framework for Disaster Risk Reduction, for volcano monitoring institutions**

### 3.2.4 Volcano monitoring institutions and citizens

All volcano observatories exist to provide early warning of volcanic hazards for the protection of society. This means that many volcano-monitoring institutions choose or are not able to be a secluded monitoring laboratory that is isolated from contact outside of technical risk management networks. Interactions outside these technical networks, with various stakeholders, including citizens, take many forms; most VMIs have some form of ‘outreach or education’ program whether formal or informal in nature. In some cases, with clear institutional boundaries, the responsibility for interacting with the public does not lie with the monitoring institution, but this is the exception rather than the rule (e.g. in Italy). There is a difficult distinction to make during these types of activity between risk education and the direct provision of advice on how to manage their risk. This condition of dynamic and ill-defined boundaries between risk warnings and risk management has in some cases prompted innovative responses from these institutions to volcano risk problems (Donovan and Oppenheimer 2015).

Many of these innovations are related to how the institutions interact with citizens with respect to their risk; in terms of assessment, communication, education, awareness and monitoring. Stirling (2007) describes some adaptations or innovations like this as radical entrepreneurship that if successful then may move on to increasing professionalism and institutionalisation. It is however challenging for an institution to change, often requiring a shock or force that necessitates an adaptation. Pelling (2008) suggests that in the case of climate change, these adaptations can often occur in 'shadow spaces' i.e. those that exist between formal institutions and are often characterised by informal or less-formal interactions between different groups – in this case between volcanologists and citizens.

As suggested above, and in the light of future adaptations encouraged by global adoption of the Sendai Framework for Disaster Risk Reduction (Table 3-1), the roles of these institutions must rarely be about data collection alone, but often include some responsibility, formal or not, for forms of risk communication (Newhall 1999; Barclay et al. 2008; Tilling 2008; Haynes et al. 2008b; Jolly 2015b) and awareness building or education (Carlino et al. 2008; Leonard et al. 2008; Donovan et al. 2013; Rouwet et al. 2013). This communication can range in scope from being solely directed at public officials, such as risk managers or local authorities, to direct communication with citizens. The effectiveness of risk communication in stimulating risk reducing adaptations is strongly determined by the accuracy of the information provided, the delivery of the message and the degree of trust that the receiver has in those transmitting the message (Haynes et al. 2008b; Pidgeon and Fischhoff 2011; Fischhoff 2013).

The consequences of volcanic risk management decisions (evacuations, restricted land usage or access at one end, loss of life or assets at the other) mean that the challenges of assessing, monitoring and managing risks can exert its toll on relations between scientists and citizens (Barclay et al. 2015), affecting dynamics of trust (e.g. Mothes et al. 2015).

### 3.2.5 An imperative for participatory monitoring?

Citizen involvement in monitoring can be in response to a lack of institutional capacity to collect enough data during an event, limited institutional capacity during a heightened crisis (e.g. as discussed in Chapter 5), as an attempt to foster or as a result of collaborative risk reduction (Chapter 4), or as a purposeful effort to enhance and sustain relationships between scientists and citizens.

International frameworks (e.g. SFDRR (UNISDR 2015a)) strongly advocate, based on a growing amount of evidence (summarised in Chapter 2), for increased citizen or community involvement in DRR at all scales, from the knowledge produced about disaster risk, through to early warning or risk management decisions. As will be suggested in this chapter, despite the varying remits of VMIs, there is a strong precedent from international DRR strategies for some form of participatory monitoring within their roles (Table 3-1). As described in Chapter 2, there are various benefits that can come as a result of participatory monitoring. These can be distilled to: knowledge production; communication and knowledge based action; and the potential for positive changes in power dynamics that can aid more equitable risk management. It is also worth re-emphasising that monitoring is often a component of participatory disaster risk assessment and management more broadly (Pelling 2007).

## 3.3 Methods

The inclusion of populations at risk in monitoring duties is not necessarily a topic that is often described in the literature or in the information from or about a VMI, so a survey (Appendix B ) was designed to understand the prevalence of citizen science in volcano monitoring.

### 3.3.1 Choice of method

The purpose of the data collection was to understand the extent of citizen participation in the work of VMIs, what forms of monitoring they were involved with, and to investigate the anticipated and actual outcomes of participation. This constituted a mixture of factual information and opinion. The best method was judged to be a questionnaire that contained a mixed range of questions.

The self-completed questionnaire survey was chosen due to the geographical spread of participants (interviews were not feasible), it could be quickly distributed and conveniently answered by participants. Questionnaires have several limitations when compared to other forms of data collection, such as the semi-structured interviews used in Chapters 4 and 5. Questionnaires suffer from not having the interviewer present, where she or he can prompt or probe or adapt the questions, they are also likely to have lower response rates and run a greater risk of missing data. Questions need to be rigorously designed and tested to minimise ambiguity in answering: the meaning needs to be clear, and in this instance clear to participants who many not necessarily be completing it in their native tongue. The structured format of them however, does help a researcher to rapidly compare the range of responses to questions and often quantify the results (Bryman 2012). In this study, a balance was needed between the number of questions and the risk that the respondents would not complete the questionnaire. The questionnaire was pre-trialled with ex-VMI scientists to test the questions. Any responses from VMI participants that weren't clear, or responses that justified some further questions were followed up over email or through supplementary interviews at international meetings to provide clarification and triangulation (Bryman and Burgess 1994).

### 3.3.2 Survey Cohort

The survey was intended for VMIs, which are represented generally by WOVO. Many VMIs are not individual members of WOVO, but rather their parent organisation is a member. WOVO was a reasonable initial classification for bounding the remits of the survey given the range of potential organisation that formally or informally monitor volcanoes. The contacts for these VMIs were obtained via WOVO and acquired over several successive international meetings. In addition to current WOVO members, the British Geological Survey (BGS) was included in the survey, due to their past membership (through the Montserrat Volcano Observatory (MVO)), their responsibility for monitoring volcanoes on or affecting British territory, and their development of a volcano citizen science app. The author was a member of the team developing the app, and BGS part funded this PhD: this is a potential source of bias, but BGS were judged to be worthy of inclusion.

### 3.3.3 Question Selection

The full range of questions are shown in Appendix B . In summary, the initial questions were designed to understand i) the nature of monitoring institution; ii) its set up and funding; iii) the who, what, where, when and why of any citizen participation in monitoring; and iv) to understand how the initiative developed. Each of these types of questions were designed to address the extent to which these existing initiatives mapped onto the rationale and motivations of citizen sciences or disaster risk reduction.

These questions were followed by a series of multiple-choice questions presenting a Likert scale, which were used to assess attitudes towards the monitoring, to determine the extent to which those working in the VMI perceived there to be benefits, and whether those benefits were those more closely associated with the particular aims of many citizen science projects or the broader aims associated with participation in DRR. The questionnaire was estimated as taking forty-five minutes to complete. It was trialled amongst colleagues and former VMI staff.

Questions in the survey were informed by relevant literatures on citizen science, participation, risk communication, DRR and volcanology (as described in Chapters 2 and 3). Questions were phrased in a mixture of formats; both restrictive and 'select all that apply' options, open ended text responses and Likert scales (Bryman 2012), enabling directly comparable responses and responses where participants were able to freely express their opinion in their own words (and language).

### 3.3.4 Questionnaire response rate

There were thirty-three complete responses to the questionnaire from twenty-nine different VMIs. Some of the VMI respondents represented several VMIs, such as Instituto Geofísico (IGEPN), Ecuador or the response from the Japanese Meteorological Agency which represented several institutions (there are sixteen VMIs recognised in Japan on WOVO's list). The survey was distributed by email to the WOVO list, at international meetings and through the recommendations of and sharing by survey respondents: a form of snowball sampling (Bryman 2012). The WOVO list contains many out of date email addresses and lacks contact details for many VMIs (WOVO Secretariat, personal communication, September 2014) as WOVO is extremely under-resourced. Some responses covered multiple VMIs and some regions, such as the Philippines, where there are many VMIs, did not respond. These factors make it difficult to calculate an exact response rate (and surveys distributed online or through snowball sampling often have issues like this (Bryman 2012)), but nevertheless the global coverage and proportion of monitored active volcanoes encapsulated by the responses is substantial (Figure 3-1 and Figure 3-2). Particularly, the organisational variance in set-up funding and number of volcanoes to be monitored is well represented in the survey (Figure 3-1).

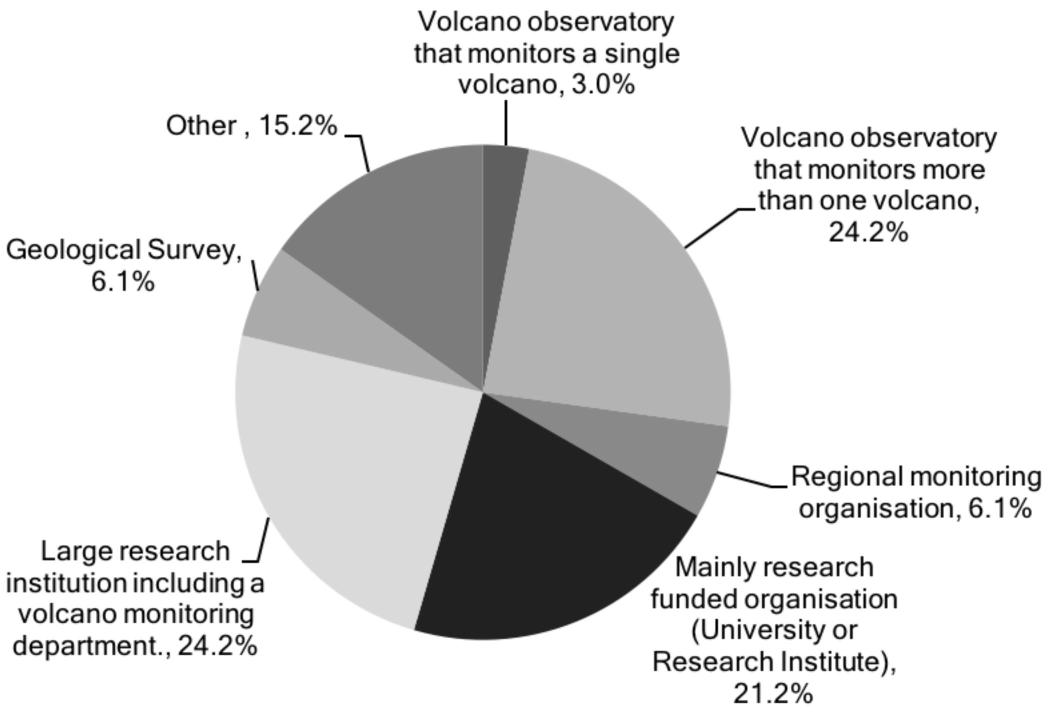


Figure 3-1 Type of VMI in survey responses

### 3.3.5 Data analysis

While the number of respondent institutions were insufficient for multi-variate statistical analyses, there were sufficient responses to provide analysis of the data. Data were plotted and analysed for trends, often using pivot tables (Bryman 2012) or filtering for responses, then tabulated (e.g. Table 3-5, Table 3-6, and Table 3-7) open-ended text responses and supplementary interviews conducted at international meetings and field visits were analysed thematically (Bernard and Ryan 2009), with themes derived both from the literature relevant to to the overall goals of the survey (e.g. (Pelling 2007; Haklay 2012) and others from Chapter 2) and adapted iteratively as they emerged from the data. The qualitative data are presented in tabulated/figure form and within the text, with illustrative quotes inserted verbatim. Multiple responses from a single institution were averaged when quantifiable and text responses were analysed for coherence between responses from the same VMI (Bryman and Burgess 1994).

### 3.3.6 Limitations of the methodology

The methodology had a number of limitations: i) WOVO is under-resourced and managed voluntarily, meaning that the email list of members was incomplete or out-dated in places (to account for this, omissions in contact details were rectified where possible), however some gaps remained; ii) although a strength of using a survey methodology is to be able to compare responses, sometimes by quantifying them, or to reach more participants who are spread geographically, surveys lack the ability to generate a deeper and more contextually grounded understanding of a subject that interviews can; iii) the survey only investigated citizen involvement in monitoring and did not explicitly ask questions about other forms of participation (although these did come up in text responses, and; iv) the survey was sent out at a similar time to another survey (as part of the work of Global Volcano Model for the UNISDR GAR 15 (UNISDR 2015b) to many of the same institutions – this unfortunate timing may in part explain a lack of responses from certain institutions as was inferred to be the case for PhilVolcs (Philippines).

## 3.4 Survey responses

The results and analysis from the survey will be presented here using a combination of figures, illustrative verbatim quotes and tables, before being expanded on and discussed in 3.5.

### 3.4.1 Response

The institutions that responded to the survey are responsible for monitoring approximately 300 potentially active volcanic centres across 24 countries, which provide a representative sample of variations in economic development, institutional funding and monitoring arrangements of the WOVO community as a whole (Table 3-2). The geographical spread of responses (Figure 3-2) in part reflects the limited number of official volcano-monitoring institutions in regions such as the African continent, where although volcanoes are monitored, there are few institutions responsible this role.

| VMI Number(1) | Development(2) | Organisation(3) | Funding(4) | Networked(5) | Participation |
|---|---|---|---|---|---|
| 1 | LM | VMI | GOV | Yes | Yes |
| 2 | LM | GS | GOV+NGO | No | Yes |
| 3 | UM(1) | RF | R | *Yes* | Yes |
| 4 | UM(1) | RF | GOV | *Yes* | Yes |
| 5 | UM(1) | RF | GOV | Yes? | Yes |
| 6 | H(2) | RI(V) | GOV + R | Yes | No |
| 7 | H(4) | RI(V) | GOV +R | Yes | No |
| 8 | H(3) | RI (V) | GOV + R + PRIV | *Yes* | Yes |
| 9 | H(2) | RI (V) | GOV +R | Yes | No |
| 10 | H(2) | RI(V) | GOV +R | Yes | Yes |
| 11 | H(6) | RF | GOV | No (?) | No |
| 12 | H(4 | RI(V) | GOV | Yes | Yes |
| 13 | H(5) | GS | GOV | Yes | Yes |
| 14 | H | RF | GOV+R | No | No |
| 15 | UM | RI(V) | GOV | No | Yes |
| 16 | H(6) | RF | GOV | No | No |
| 17 | H(7) | GS | GOV+R+PRIV | Yes | Yes |
| 18 | H(5) | GS | GOV | Yes | No |
| 19 | UM | RF | GOV+NGO | Yes | Yes |
| 20 | UM | RI(V) | GOV | Yes | Yes |
| 21 | H | RI(V) +GS | GOV | Yes | No |
| 22 | H | RF | GOV+R | Yes | Yes |
| 23 | H(3) | RI(V) | GOV+ R+ PRIV | *Yes* | Yes |
| 24 | UM | RMI | GOV+R+PRIV | Yes | Yes |
| 25 | H(5) | GS | GOV | Yes | Yes |
| 26 | LM | RI(V) | GOV | No | No |
| 27 | H(2) | RI(V) | GOV +R | Yes | No |
| 28 | UM | RMI | GOV +R | Yes | No |
| 29 | LM | VMI | GOV | No | Yes |
| 30 | H(3) | RI(V) | GOV | *Yes* | Yes |
| 31 | UM | VMI | GOV | No | Yes |
| 32 | H(7) | GS+RI(V) | GOV | No | Yes |

**Table 3-2 Summary of responses from volcano monitoring institutions to illustrate, degree of development, no. of volcanoes for which responsible, and source of funds for monitoring.**

Notes

(1) Institutions are numbered here sequentially and cannot be identified from their other codes
(2) Classification of the country or countries in terms of World Bank Degree of Economic Development, H high median income, UM upper Middle income, LM Lower Middle , L Low income (where a number identifies different institutions from one country)
(3) Type of monitoring organisation, VMI – Institution dedicated to the monitoring of a single or multiple volcanoes, RMI – institution dedicated to monitoring volcanoes in multiple countries across a region, RF – monitoring organisation within an institution mainly funded for research or higher education, RI(V) research-led or monitoring institution with a dedicated volcano monitoring department, GS Geological Survey with volcano monitoring department

(4) Dominant sources of funding – GOV Government (Federal, local and regional), NGO funding from a non-governmental agency or overseas aid, PRI – private donors including insurance agencies, R – grant-won research funding
(5) Indicator of whether organisation is within a national network of organisations also tasked with volcano monitoring (not including international agencies such as VAAC and NASA). If yes is italicised then this indicates that networked organisations have different responsibilities for the same volcanic systems.

The majority of responding institutions are involved in some form of participatory monitoring initiatives (66%) and it is not possible to correlate this with any regional patterns of engagement (Figure 3-2). Some institutions in lesser economically developed countries engage in citizen science (e.g. Nicaragua) and some do not (e.g. Democratic Republic of Congo). The same is true for more economically developed countries. For example, in the USA, within a single organisation – the USGS – participatory monitoring involvement varies considerably across their specific observatory institutions, with the Alaskan Volcano Observatory regularly engaging with citizens for data collection (Figure 3-5; Wallace et al. 2015), whereas the Cascades Volcano Observatory does not.

Globally, those institutions with a member of staff responsible for education and outreach (of which 72% have such a person) are more likely (70%) to have participatory monitoring initiatives than those without (54%). However, very few of these participatory monitoring initiatives are coordinated by the education and outreach member of staff within those institutions that have one (25%).

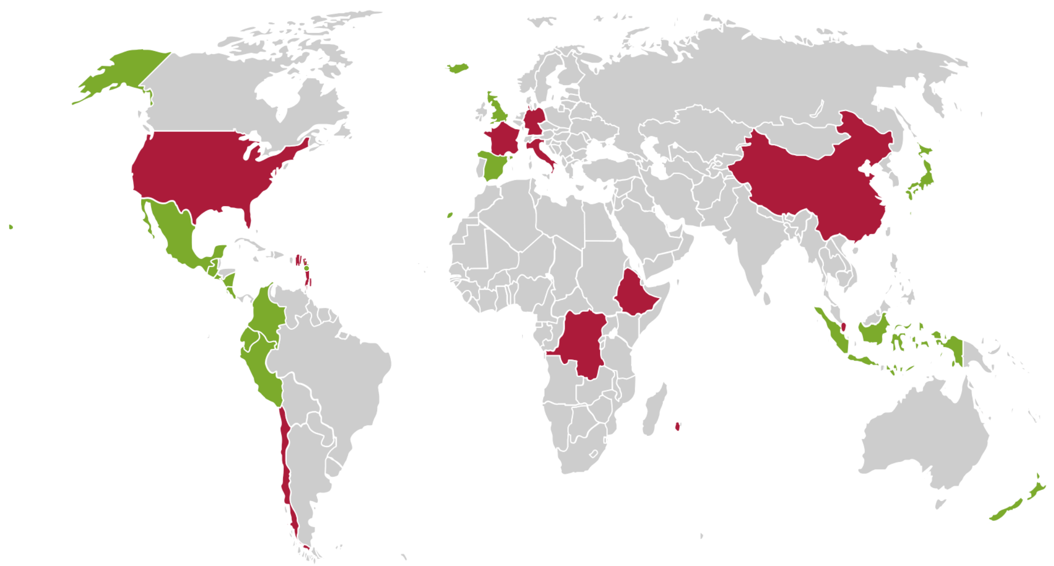


**Figure 3-2 Map showing the global distribution of survey responses and extent of participatory monitoring**

### 3.4.2 Forms of participatory monitoring

Figure 3-3, summarises the main forms of participatory monitoring by VMIs. The large majority have some direct association with the provision of qualitative visual observations (observations (21%) and visual accounts (14%)) and photographs of phenomena (17%). Many of the data collection methods described in the text responses are also qualitative, even those concerning tephra fall (17%), where more quantitative approaches to citizen-derived data collection are reasonably ad-hoc. There are only a few notable examples of systematic forms of data collection (e.g. *myVolcano* and *Is ash falling?*, see Figure 3-4 and Figure 3-5), although seemingly from the small sample of examples, this form of volcanological citizen science is the most publishable (Bernard 2013; Stevenson et al. 2013; Wallace et al. 2015). The use of citizens as field guides or field assistants is common amongst volcanologists anecdotally, but not prevalent in the survey responses. There is limited evidence to date of citizen science input into public participatory geographical information systems involving volcano-monitoring institutions, despite significant usage in other fields (as described in Chapter 2).

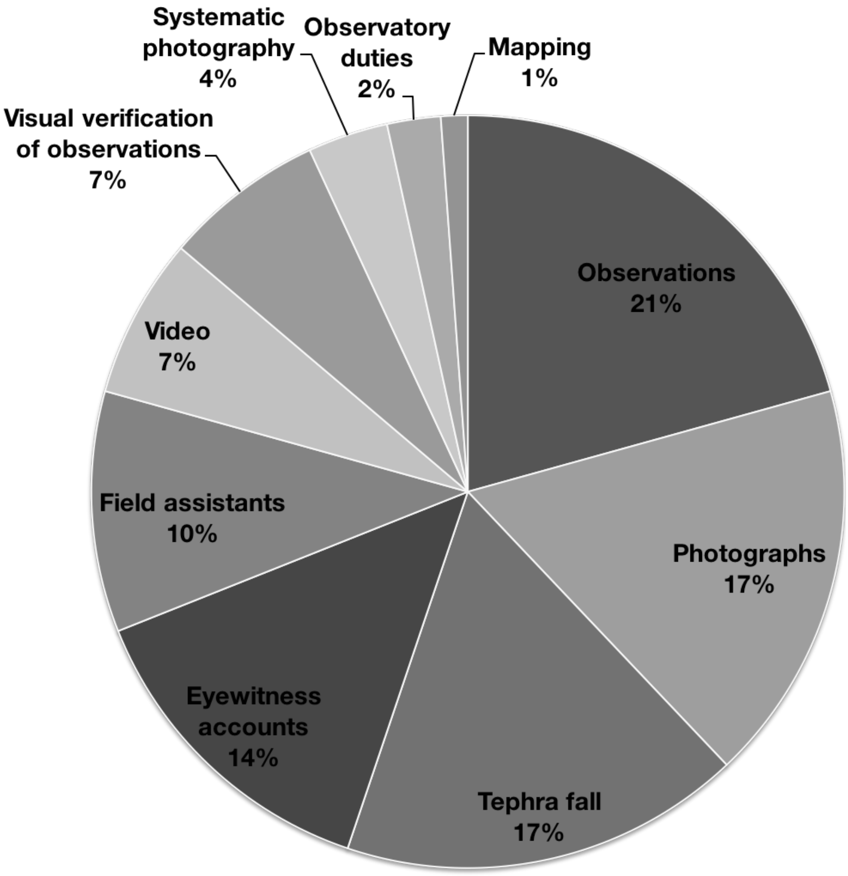


Figure 3-3 Forms of participatory monitoring (percentage of respondents reporting each form)

What is very clear from the survey responses is that persistent or systematic forms of citizen science data collection are rare, with limited numbers of respondents suggesting that citizens regularly contribute observations or contribute data that are collected over longer periods of time (Figure 3-7).

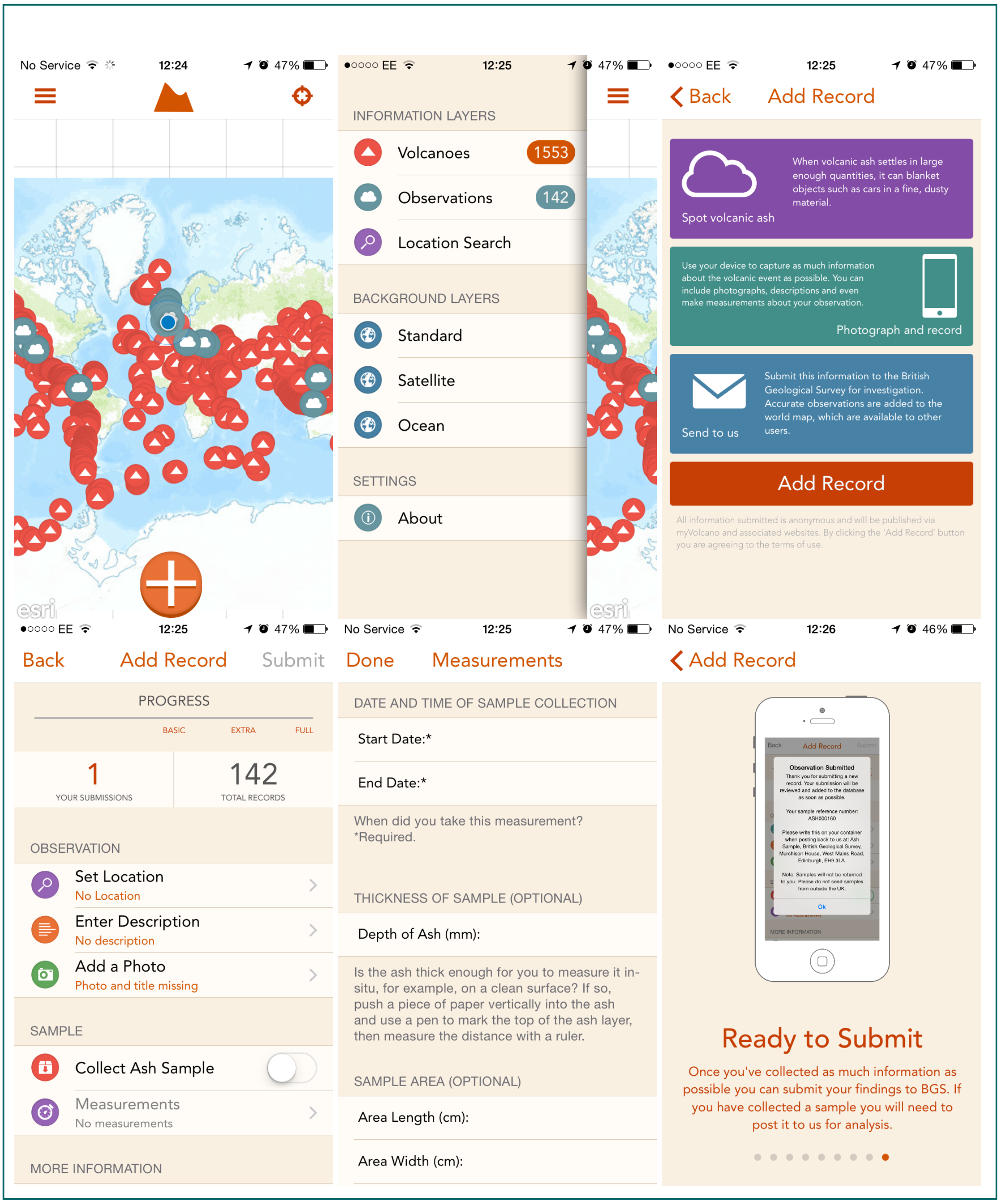


**Figure 3-4 Photo showing screenshots from BGS's myVolcano app for volcano citizen science**

### 3.4.2.1 Coordination of participatory monitoring

Most institutions coordinate participatory monitoring initiatives in a number of ways simultaneously, via face-to-face meetings (77%), telephone (68%) or email (50%). Less common are website based initiatives, or those that are carried out within schools. Clearly, email or website based forms of participatory monitoring can in theory increase the number of participants through reach and ease of access, but email is likely to limit interactions between stakeholders. The responses show that in most cases a scientist in the institution coordinates the participatory monitoring (Figure 3-6).

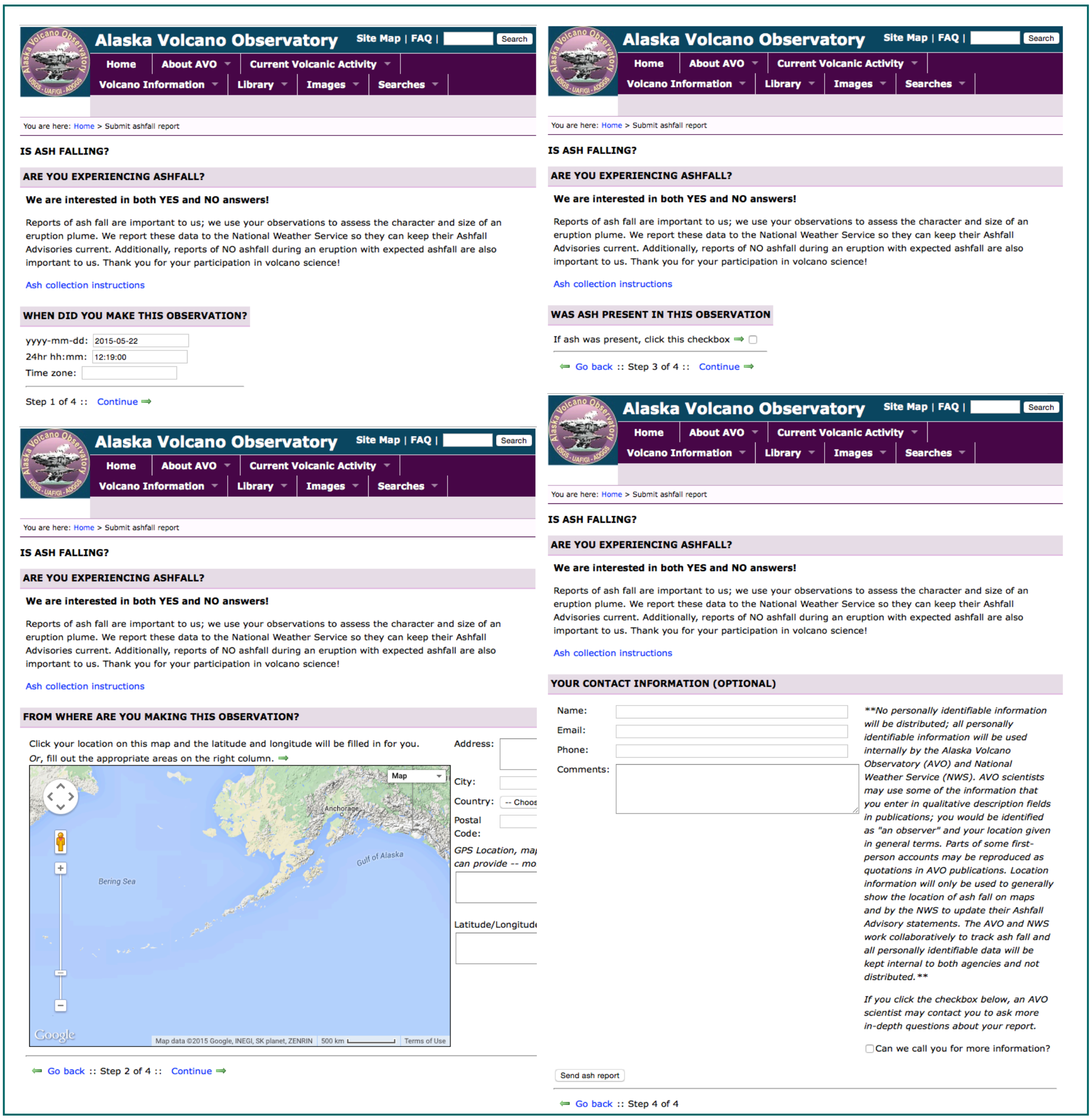


**Figure 3-5 Screenshots from Alaska Volcano Observatory's *Is Ash Falling?* website**

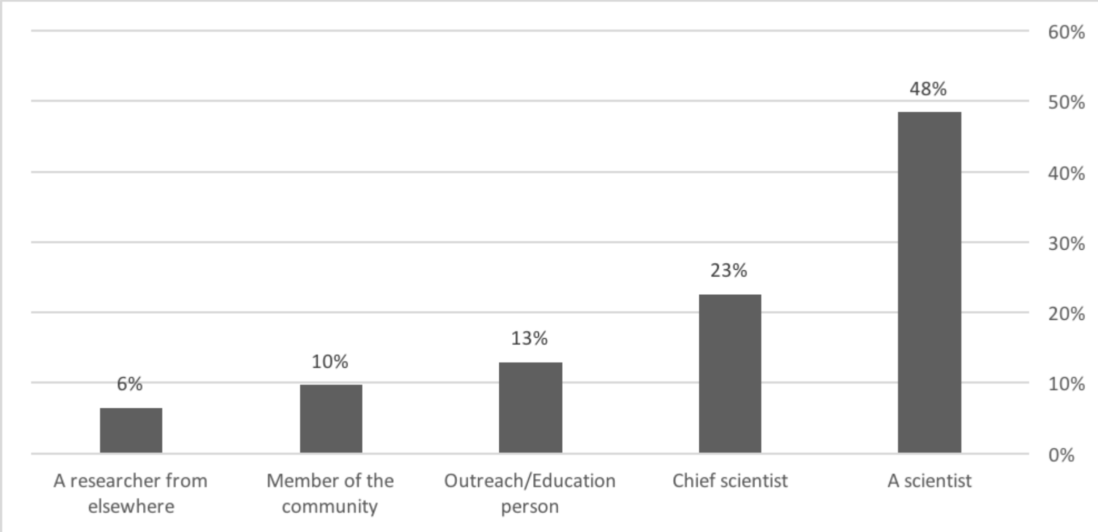


**Figure 3-6 Who manages the participation?**

### 3.4.2.2 Reported forms of participatory monitoring.

Most volcano participatory monitoring data are collected during periods of eruptive activity. Within those periods of activity, a greater proportion of the data are collected following specific eruptive events. Some other initiatives are for particular projects (e.g. sulphur dioxide monitoring in Saint Lucia). Only a small number of institutions state in the survey that they are involved in initiatives that continue over longer time periods or continuously. For example the regular photographs of White Island sent by tourist operators to GNS (Institute of Geological and Nuclear Sciences) in New Zealand, the *vigía* network in Ecuador (Chapter 4), examples in Figure 3-4 & Figure 3-5, or regular observations by volunteer observers around volcanoes in Guatemala.

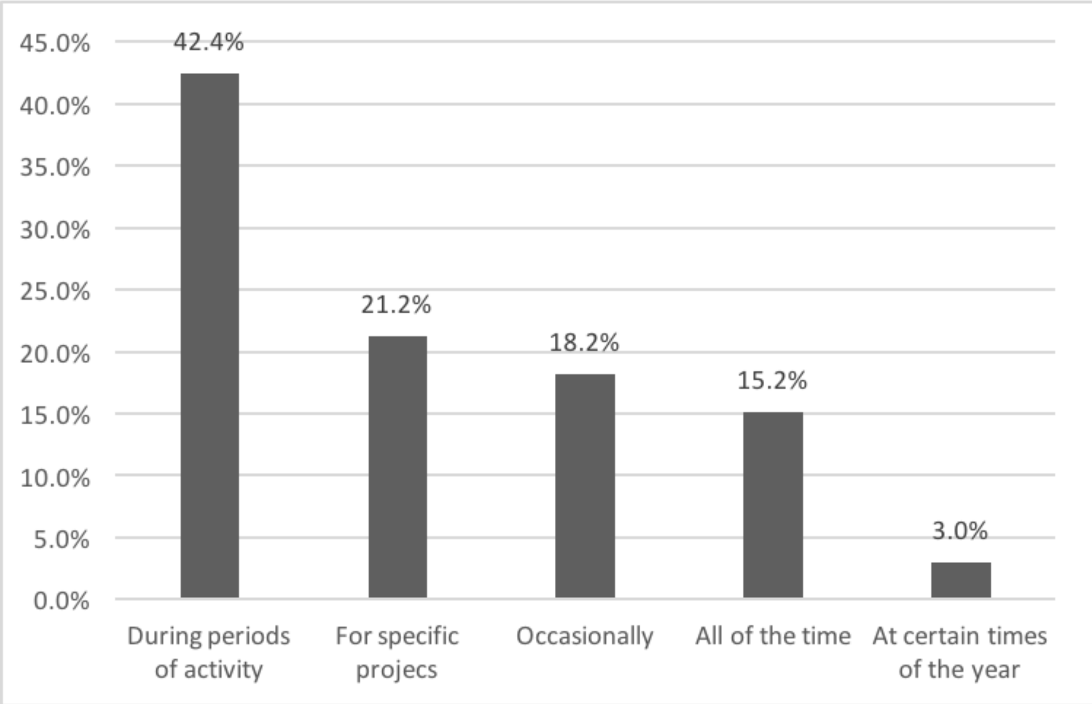


**Figure 3-7 When are citizens participating?**

### 3.4.3 Rationales for doing participatory monitoring

Most respondents state that participatory monitoring started in an ad-hoc manner, through trial and error, casual encounters with people who offered their help, or it came about as a result of discussions with the public. Few observatories set out with a deliberate plan for participatory monitoring. Some started because they needed to fill knowledge gaps, others because citizens volunteered information, and it was seen to be of value.

The predominant rationales for participatory monitoring initiatives are because of gaps in data, often occurring during an eruption when there are a lot of data to collect and limited resource (Table 3-3). These data gaps take various forms; e.g. limited resources to record all visual observations during eruptions, citizens are often the first to see new activity or citizen based observations of phenomena such as tephra fall can cover wider areas than those of the institutions'. One respondent describes this:

> *"They (citizens) are on the spot, so can make observations and collect ash quicker than we can."*

**Motivations for data collection**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| During an eruption members of the public gather valuable data that we would otherwise be unable to collect. | 0 | 2 | 3 | 4 | 12 | 1 |
| The observatory has limited resources, so it would be difficult to comprehensively monitor without members of the public helping. | 4 | 3 | 3 | 8 | 4 | 0 |
| The public collect forms of data that are not prioritised by the scientists but which are useful for monitoring. | 0 | 2 | 2 | 12 | 3 | 3 |
| The public collect forms of data that are not prioritised by the scientists but which are useful for research. | 0 | 3 | 2 | 14 | 3 | 0 |

**Table 3-3 Likert responses about data collection (data shaded for density of response)**

Participatory monitoring is also used as a means of public engagement by volcano-monitoring institutions (Table 3-3), often in the form of school-based activities such as hosting simple seismometers at schools. In other fields it is suggested that being involved in science as a process can lead to a greater uptake of scientific literacy and awareness (Conradt and List 2009; Dickinson et al. 2012; Tulloch et al. 2013).

**Motivations for participatory monitoring**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| We involve the public because they want to be involved. | 1 | 1 | 3 | 10 | 6 | 1 |
| We involve the public as a way of educating them about the volcano and its hazards. | 0 | 1 | 3 | 13 | 4 | 1 |
| We involve the public in an effort to increase their trust in the advice given by our organisation. | 1 | 0 | 5 | 12 | 3 | 1 |

**Table 3-4 Likert responses about motivations for VMIs doing participatory monitoring (data shaded for density of response)**

Some of the initiatives are for the purposes of early warning, or fulfil that role as a one off in cases where citizens are often the first to see new activity (Table 3-3). However, there are examples of more structured forms of participatory monitoring and its incorporation into early warning in Ecuador, New Zealand and Alaska.

Many respondents state that the citizens want or ask to be involved in monitoring activities, but few agree that their institutions take part in participatory monitoring simply because citizens would like to be involved.

However, all institutions are aware, have experienced, or indeed expect that participatory monitoring may improve relationships with citizens (Table 3-4 & Table 3-5), as suggested here:

> *"If they know us as people, they are more likely to trust our judgements when we have critical messages."*

Similarly they all agree or strongly agree that good relationships are important for the communication of risk, uptake of hazard information and that participation acts to enhance trust in decisions made or advised by monitoring institutions (Table 3-5), as supported by the findings of Fischhoff (2013) and others (see Chapter 2).

| **Percieved outcomes** | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Involving the public improves our relationship with them | 0 | 0 | 0 | 10 | 12 | 0 |
| Improving our relationship with the public increases the effectiveness of our risk communication | 0 | 0 | 0 | 8 | 14 | 0 |
| Involving the public improves their uptake of hazard knowledge/awareness | 0 | 0 | 0 | 9 | 12 | 1 |
| Involving the public is important for the collection/generation of data for research on volcanic phenomena | 0 | 3 | 3 | 8 | 6 | 2 |
| Involving the public means that we can better understand what happens during an eruptive event | 0 | 2 | 5 | 8 | 5 | 2 |
| Involving the public increases their trust in us | 0 | 0 | 0 | 9 | 13 | 0 |

**Table 3-5 VMI perceived outcomes from participatory monitoring (data shaded for density of response)**

### 3.4.4 Reservations for VMIs that do participatory monitoring

Some state that they are not aware of the potential benefits and therefore do not allocate much resource to it (Table 3-6), as illustrated by a respondent:

> *"I think the resources required to engage the public outweigh the perceived benefits at this stage. Continuing to receive their observations, particularly during an eruption, supplements monitoring data and requires fewer resources than more active engagement. Receiving observations as photos is useful, as it removes the public interpretation layer. Receiving evidence on*

*how public engagement would benefit relationships and communication would support more active engagement and help balance the drain on resources."*

Whilst most respondents suggest that the data collected are of reasonable quality (Figure 3-8), some are reticent to agree that there is a need for following a rigorous scientific method (e.g. see the descriptions given for collecting ash in Alaska (Figure 3-5) or for *myVolcano* (Figure 3-4)), and others state that there are barriers to overcome regarding scientists trusting any data not collected by themselves:

*"Frankly, most scientists I have spoken to - at our observatory and elsewhere - trust no one but themselves and trusted colleagues to collect data. If data is taken by people they don't know, then it is taken 'with a grain of salt', and noted as such in publications."*

**Reservations for VMIs that do participatory monitoring**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Our scientists and monitoring network provide all of the data/observations that we need | 2 | 11 | 4 | 4 | 0 | 1 |
| Data/observations collected by members of the public is/would be too basic to be of scientific use | 2 | 10 | 4 | 3 | 0 | 2 |
| Data/observations collected by members of the public is/would be too poor in quality to be of use | 2 | 14 | 4 | 1 | 0 | 1 |
| Involving the public is a drain on resources | 7 | 7 | 3 | 3 | 0 | 1 |
| Close involvement with the public could affect scientists' objectivity when giving advice/making decisions | 6 | 8 | 3 | 3 | 0 | 1 |
| Involving the public could increase the spread of competing (or negative) messages about the volcano and its hazards | 2 | 11 | 1 | 3 | 1 | 3 |
| Members of the public do not want to be involved | 2 | 13 | 3 | 1 | 0 | 3 |

**Table 3-6 Reservations for VMIs that do participatory monitoring**

There is variance in the responses that relate towards the scientific value of the data (Table 3-6 Reservations for VMIs that do participatory monitoringThe degree to which these data are assigned value beyond that associated with risk communication varies between settings, something which the analysis of the qualitative survey data elucidates further. Whilst most think that the data collected are of reasonable or good quality, some respondents question the variable quality of the data and therefore its usage:

> *"…(the data are) highly variable, this is pivotal, and a major reason that we do not strive to do more of it."*

Others agree with this, but also reflect a pragmatic attitude to citizen data being useful when it is all there is:

> *"…[the data are] very poor compared to monitoring data. If there is no monitoring data, then public observations are better than nothing."*

However, a response from an institution that has a more systematic or formalised form of participatory monitoring in place is rather different:

> *"[The participants are] stunningly detailed collectors - we give many options and many people pick the most complicated forms of collections which give us the most information."*

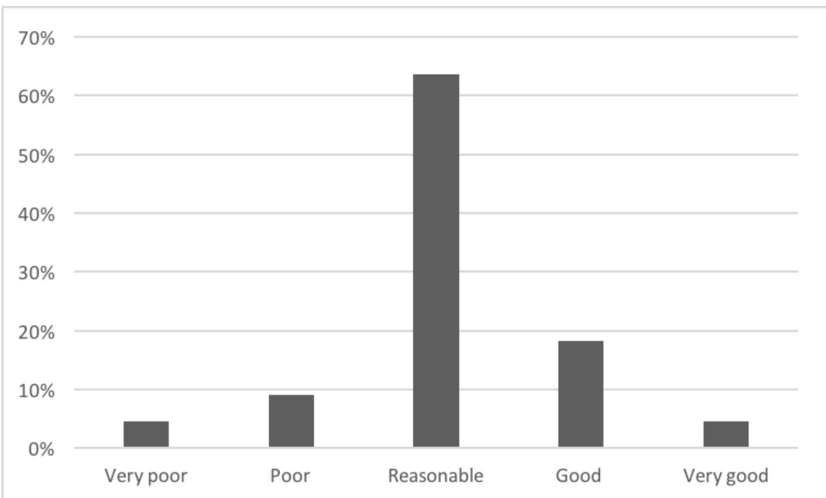


**Figure 3-8 Participatory monitoring data quality**

### 3.4.5 Reservations from respondents in VMIs that do not engage in participatory monitoring

The questions for this (Likert and open text response formats) mirrored those asked in (Table 3-6), but were only asked of those that responded ‘no’ to an earlier question on citizen participation (Table 3-2). Those institutions that do not engage in it do not present consistent reasons for this (Table 3-7). Some state that they do not have the resources available to effectively manage or involve participants. Several institutions cite a lack of regular volcanic activity as a dampener on participatory monitoring activities.

| Why some VMIs don't do participatory monitoring | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Our scientists and monitoring network provide all of the data/observations that we need | 1 | 6 | 0 | 3 | 1 | 1 |
| Data/observations collected by members of the public is/would be too basic to be of use | 2 | 3 | 1 | 4 | 0 | 2 |
| Data/observations collected by members of the public is/would be too poor in quality to be of use | 2 | 2 | 2 | 3 | 0 | 3 |
| Involving the public is a drain on resources/time | 2 | 6 | 1 | 3 | 0 | 0 |
| Close involvement with the public could affect scientists' objectivity when giving advice/making decisions | 2 | 5 | 2 | 2 | 0 | 1 |
| Involving the public could increase the spread of competing (or negative) messages about the volcano and its hazards | 1 | 5 | 1 | 4 | 0 | 1 |
| Not enough people want to be involved | 0 | 3 | 4 | 1 | 0 | 4 |

Table 3-7 Why some VMIs do not do participatory monitoring (data shaded for density of response)

Three of the eleven respondents disagreed or strongly disagreed with all questions in Table 3-7, suggesting that they did not identify with any of the phrases provided to explain their lack of participatory monitoring initiatives. The respondents are all from institutions that are predominantly research VMIs based in high income countries (in relation to the processes or outcomes of their monitoring), which may explain their lack of engagement. However, these three research VMIs do have members of staff responsible for public outreach.

When these three respondents are filtered out of the results, the majority of 'no' respondents suggested that either the data would be too simple to be of use, or of insufficient quality. The ambiguity over the quality of the data echoes some of the responses from those that do engage in participatory monitoring. Three respondents from the twenty-one VMIs who have taken part in citizen science initiatives in the past plan not to engage in the future. Two of these cite questions over the usefulness of the data as the potential issue.

Other institutions who have never engaged in participatory monitoring also explain their lack of engagement to date by suggesting that engaging with the public in this way is outside of their institution's remit; i.e. other national agencies communicate and interact with the public:

> *"No one organization has resources to do everything. Perhaps it works well for organizations to stand and support one and another, and for each organization to focus on what they do best and fits their funding mission."*

This is surprising to an extent because eight of the eleven institutions that do not use participatory monitoring have members of staff responsible for outreach with the public. This suggests that a direct connection between citizen science initiatives and risk or hazard awareness programs has yet to be made in this instance.

Some of the eleven institutions state that citizen science is less needed due to increasing automation of monitoring along with more sophisticated and technological means of communication. Importantly, there is a recognition that the 'public' do have potential for participation, only one respondent suggested a lack of basic volcanological knowledge amongst citizens as a reason for not having incorporated participatory monitoring in the past. Even in this case this was identified as a potential motivation for the future if it were to lead to enhanced awareness.

Of the eleven responses, the three from more developed countries were more concerned about how participatory monitoring might create or encourage the spread of competing risk messages. A respondent from one of these institutions elaborated on this, suggesting that there are concerns with empowering citizens to assist with monitoring, in case of harmful interpretations of the data:

> *"I get the feeling that our organisation is hesitant to involve the public in monitoring, as it might cause the public to think they can interpret the data themselves (false confidence), and therefore the scientists aren't needed or trusted as much."*

This concern appears to be shared by some scientists, triangulated by the author's observations following questions during conference presentations and conversations with a purpose with scientists. What is also clear from an analysis of the responses is that different VMIs adopt different cultures and ways of acting, often in response to their operating environment. Thus, for those that do not engage in participatory monitoring, there is an apparent lack of coherence in why not (Table 3-7), because those reasons are highly context specific.

### 3.4.6 Future plans

When asked whether or not they would do participatory monitoring in the future, 59% of institutions who were or had done participatory monitoring said that they would in the future, 41% said maybe. Of those that are not currently doing participation, 27% said no, 27% said yes and 45% said maybe to future initiatives. Many of the 'maybe' responses for both groups cited a lack of useful data, limited resources, a lack of management or changes in the nature of risk governance as factors. Those that said no mostly had questions over the usefulness of the data. Whilst many see considerable potential, they often state a lack of resource as a limiting factor, as described by a respondent from Central America:

*"I have wanted to establish key observations points where people could take photos of activity (explosions, lahars) and do further ash sampling. I wish I could organize more. It is only restricted through time constraints."*

Many other respondents state that in the future, involvement of the public is inevitable and likely to increase, suggesting that if done well it can only add value. One respondent provides a detailed and thoughtful response to a question asking for any additional views:

*"I think every observatory/culture is different. Obviously, some can gain much from public participation in monitoring and research, while other observatories have less use for it. When our observatory obtains help from 'the public', we are usually in need of brawn required to haul and install equipment, field assistance, or to do repetitive work that requires some training…to sum it all, our observatory is sufficiently limited on resources such that we are not altruistic about creating jobs for the enlightenment of the public. We pick and choose individuals carefully who can fill our needs gaps in monitoring and research. We see education as a major place for public involvement, and we concentrate efforts on training of people at the grass roots level. We see 'involving the public' in other volcano-related venues more broadly as a role that can best be done by organizational partners who specialize in education - encouraging the making of observations, collecting data in areas under their jurisdiction, etc."*

Others advocate less for participatory monitoring but more for public participation in other observatory roles such as forms of deliberation and two-way risk communication, where scientists tell citizens about the volcano, get feedback on what messages are or are not successful, and how to best inform the public.

## 3.5 Discussion

The objective of the survey was to understand the nature of participatory monitoring between citizens and volcano monitoring institutions worldwide. The survey explored where participation was occurring and why or why not; what kinds of data the citizens were collecting or analysing; when this was occurring and what outcomes there were for the citizens or VMIs. The overarching aim of this was to understand the different roles that citizens may play in risk reduction around volcanoes, through the production of knowledge that is used to develop understanding of volcanic hazards, for risk management planning, or to facilitate early warning.

The responses came from a large variety of VMIs, with different funding sources, roles, responsibilities, cultures and risk governance operating environments (Table 3-2). These factors, coupled with variable extents of volcanic activity across different contexts, resulted in VMIs contributing a range of different insights for the central research questions.

Most of the participatory monitoring approaches used by the responding institutions vary between qualitative observation or photographic methods and more quantitative ash sampling approaches. An analysis of the survey data suggests that of those initiatives that are more quantitative or systematic, e.g. tephra fall monitoring, and are therefore likely to contribute to data sets and increase knowledge of volcanic phenomena, the majority are initiated by scientists. The data are often collected and used by the institution, with limited further input from the participants. Forms of participatory monitoring, such as photographs of eruptions are more likely to be volunteered by the participants, rather than asked for by the institutions. These observations likely add to the general understanding of eruptive events, but are less likely to contribute to longer-term or sustained knowledge production. Of note and limited occurrence are those initiatives that were collaboratively designed and implemented. Initiatives like this have had considerable impact in other fields (as discussed in Chapter 2), due to better problem formulation, longevity of study and the empowerment of participants (Chapter 4 & Conrad and Hilchey (2011)).

What characterises most of the participatory monitoring initiatives that volcano-monitoring institutions are involved in or coordinating is that they are often restricted to eruptive events or short-lived projects. In the case of tephra fall citizen science, observations are often collected purposively with direct contact between scientists and citizens or formally through websites or mobile apps, with some examples of crowd-sourced data from social media. With the exception of the latter approach, most data are volunteered. Of notable absence in the survey responses are descriptions of PGIS type methodologies, and as seen in other areas this is an avenue of considerable potential (Goodchild 2007; Haklay 2013).

The clearest consensus from the results was the perceived value of participatory monitoring in fostering trust-based relationships between VMIs and at risk citizens. This is consistent with the documented benefits of citizen science and participatory science from elsewhere (e.g. Bonney et. al. 2009). There is however a lack of insight available in the responses about the nature of that trust, and in particular who has trust in whose processes and decisions.

Although those that don't do participatory monitoring have clear reasons for not doing it. From the survey data, there is no strong consensus amongst these respondents on why not. However, many of them agreed about concerns around the usefulness of the data. Other evidence suggests that those institutions that do not do participatory monitoring, and those that don't resource it much, may simply be lacking evidence of how to do it successfully or the role it plays in improving hazard and risk awareness or suitable opportunity for it due to a lack of eruptions.

### 3.5.1 Data, risk reducing knowledge and empowerment

The frameworks of Haklay (2012) and Pelling (2007) discussed in Chapter 2 (Section 2.8 and Figure 3-10) can help develop understanding of how these initiatives vary and what those variations mean for the different roles of citizens and the potential risk reducing outcomes of participatory monitoring.

**Level 4 'Extreme Citizen Science'**

- Collaborative science - problem definition, data collection and analysis

**Level 3 'Participatory Science'**

- Participation in problem definition and data collection

**Level 2 'Distributed intelligence'**

- Citizens as basic interpreters
- Volunteered thinking

**Level 1 'Crowdsourcing**

- Citizens as sensors
- Volunteered computing

**Figure 3-9 Haklay's levels, reproduced from Haklay (2012)**

How the data are collected, analysed or interpreted and then used varies across the VMIs. Some do participatory monitoring only for the purposes of data collection, some expect that doing so will improve relational trust, and others go further expecting or having seen wider risk reduction outcomes as a result of participatory monitoring (e.g. Ecuador and New Zealand). As discussed in Chapter 2, the extent of citizen involvement in the process of participatory monitoring, in terms of how collaborative or scientist led an initiative is, can affect the agency of a citizen or community for making or implementing risk reducing adaptations based on the knowledge produced.

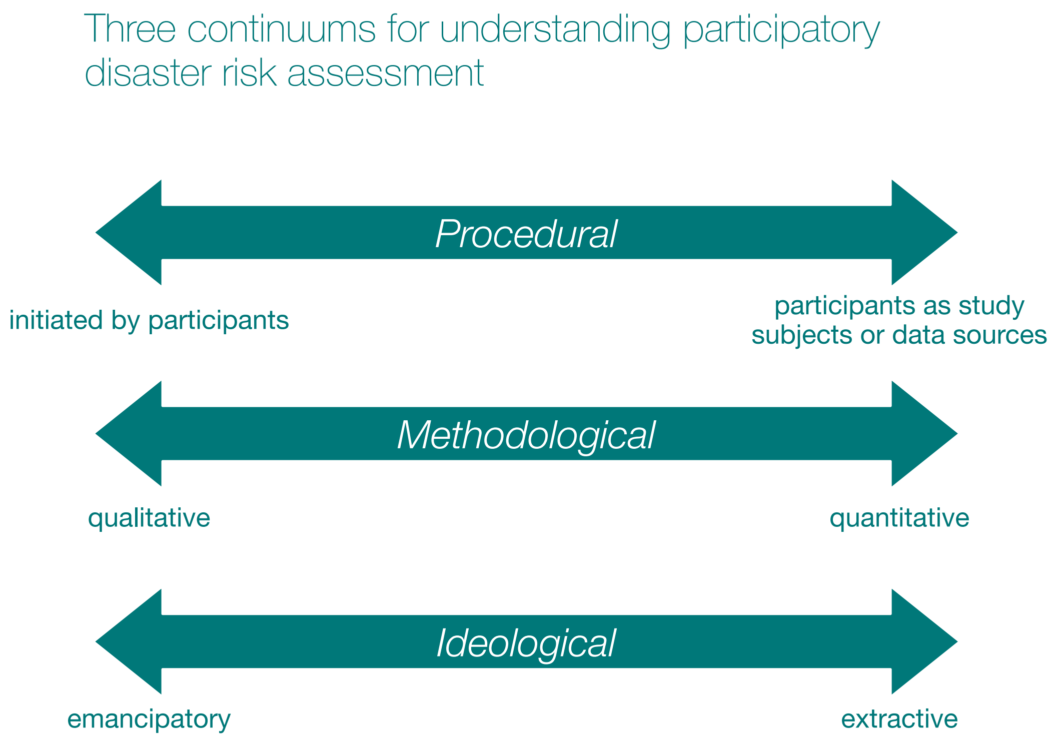


**Figure 3-10 Pelling's continuums, based on Pelling (2007)**

Using Haklay's (2012) framework (Section 2.7.3) many of the approaches sit between level 2 'Distributed Intelligence' where citizens are more than passive sensors, often providing some simple interpretation or volunteered thinking, and level 3 'Participatory Science'. An example of simple interpretation might be citizens contributing eyewitness accounts or deciding when to take photographs and of what phenomena during an eruption.

Those approaches that are closer to Level 3, where citizens are included in both problem definition and data collection are exemplified by citizens monitoring a threat to themselves with help from scientists, such as tephra fall or lahar hazards in Ecuador or New Zealand. Other examples of participatory monitoring that could be described as Level 3 are where citizens are the first to see volcanic activity (defining the problem) and contacting scientists to report information (data collection and communication). There are relatively few examples of participatory monitoring that might be classed as level 4 'Collaborative Science' other than the *vigías* network in Ecuador where citizens sometimes interpret data and make decisions based on it in place or ahead of formal risk management decision making processes (Mothes et al. 2015). This will be described in more detail in Chapters 4 and 5. Also, less common are examples of Level 1 'Crowdsourcing' where scientists either engage with citizens as sensors or use volunteered computing (for examples see Chapter 2). However, the advent of social media potentially changes this dynamic, further widening participation, but also creating ambiguity between volunteered and non-volunteered (publically available) data that can be of use to VMIs or other citizens. Therefore, in the future we should expect to there to be more 'participating' citizens at level 1, where they are effectively crowdsourced sensors. The myVolcano app from the British Geological Survey says that it is crowdsourcing (BGS 2014), but is more comparable to Level 2 of Haklay's framework as citizens choose when and what to sample or photograph and then volunteer this information to scientists or other users. Finally, some of the approaches have citizens participating at different levels simultaneously (e.g. Alaska or Ecuador).

Pelling's (2007) framework (described in Chapter 2, Figure 3-10) also helps to distinguish the participatory monitoring approaches in the questionnaire from one another. Taking the procedural continuum, many of the approaches in the survey have a role for citizens as data sources, but some such as new eyewitness accounts of eruptions or voluntary photo submissions are examples of citizens initiating participation. Except for some notable examples (e.g. Alaska or BGS) much of the data collected by the participatory monitoring are qualitative (Figure 3-3), which are in some ways easier for citizens to collect and in part related to the ad-hoc nature of much of the participatory monitoring described in the questionnaire responses, where the collection of data that are quantitative requires some more planning ahead of an event.

The seemingly 'extractive' nature (if compared to the ideological continuum in Figure 3-10) of many of the approaches described in this chapter may reflect volcano-monitoring institution's primary role as part of a more formal risk management structure, rather than an institution designed to empower communities to make risk reducing adaptations. They are often not set up to communicate with citizens, coordinate responses or make risk management decisions. The most common roles is that they monitor, analyse, interpret and communicate recommendations – normally within a formal risk management structure –, i.e. to another agency. Therefore, a difference exists between what participatory monitoring may look like in different risk governance contexts. Inequalities of risk, particularly in developing countries mean that very often a goal of participation in DRR should be to empower citizens to make their own risk reducing adaptations, thus reducing vulnerability and facilitating a transition to less inequality, helping to reduce the disproportionate ways in which disasters affect the poor.

There is little evidence, as yet, that the projects with VMIs are being deliberately used to help those who do not yet have a voice in decision-making (where decision-making in this context includes decisions to reduce risk) or to use collaborative science to document contentious problems around volcano risk management.  Participation is also not equal, 7 from 22 self-identified that their participants were predominantly male (10 from 22 identifying a more deliberate mix of genders) and some respondents that they were dis-proportionately engaging with community elders or professionals (in response to free text question 'Please give us any information that you can about profile of the people who take part, such as their age distribution, their gender, or their social or occupational background'). This is somewhat in contrast with the often strongly normative rationales for participatory DRR described in Chapter 2.

This study has examined participatory monitoring globally from the perspective of VMIs, across many different risk governance contexts, some of which have limited opportunities for citizens to participate in monitoring, and where their roles are normally restricted to 'citizens as sensors' or 'distributed intelligence' (Haklay 2012). With such contextual variance it is helpful to consider that Pelling (2007) suggests that it is acceptable to do PDRA (of which monitoring is a component) for data alone, i.e. without the approach being empowering, but notes the limited additional benefits beyond the data themselves when initiatives are carried out in this way. There is however, evidence in the responses that some participatory monitoring around volcanoes is principally empowering, either through enhanced relational trust or because the monitoring forms part of an early warning system that enables citizens to make risk reducing adaptations. Further investigation that understands these dynamics from the perspective of citizens at risk is discussed in subsequent chapters.

As discussed in Chapter 2, it is perhaps important to not consider extractive approaches to participation to be deficient in terms of their potential risk reducing outcomes, despite criticism of these forms of participation in DRR and development more widely (Le De et al. 2014). Rather, 'extractive' could be considered as a neutral term, given that evidence from similar projects in other fields (normally labelled as citizen science) suggests that data collected in this way can be of considerable value (Conrad and Hilchey 2011; Haklay 2013). It is perhaps here that the somewhat unique role of a VMI and that how they operate with other institutions or authorities within the context of broader DRM may restrict many of the participatory monitoring approaches to be more extractive than they are emancipatory or empowering.

Nonetheless, citizens do not necessarily need to own the outputs or become their own risk managers to become empowered; the act of data being used to inform better decisions that reduce risk is empowering for citizens and the choices that they can make, and in opening up the opportunities that they can have (Pelling 2007). This notion is further supported by ideas that power and empowerment are not necessarily a zero-sum situation (Chambers, 2006) , where for a more powerful person (or an upper) to empower someone less powerful (a lower) that there needs to be a transfer in power between the two. Evidence presented in this chapter suggests that scientists (uppers) are in a good place to empower citizens (lowers) by engaging with them in the process of monitoring volcanoes without compromising or having to change the structures and ways that risk is governed by authorities and institutions, consistent with findings elsewhere (e.g. Chambers (2006b)). Thus, via engagement with participatory monitoring, even in localities where risk is managed for citizens and not by them, there is still considerable potential to empower people through involvement in the process and increased awareness and understanding of, and between, stakeholders.

### 3.5.2 Making participatory monitoring work

If the various contexts in a locality mean that the only forms of sustainable participation are restricted to those where data are volunteered by participants and then used and owned by scientists, then they should be designed for the purposes of building data sets, i.e. by being systematic, if they are to contribute to risk reduction. Simply collecting data on an ad-hoc basis is less likely to either generate significant new knowledge or impact relationships. Evidence in the survey and the literature (e.g. Conrad and Hilchey (2011); Haklay (2012)) suggests there is often a tension between maximising the resolution of data, normally by having more participants collecting more data, and scientists having the time to develop relationships with the participants; potentially facilitating knowledge exchange and developing trust. The prevalence of ad-hoc forms of participatory monitoring in the survey responses perhaps in part explains why there are limited modern examples of citizen science data generating new research insights in volcanology (e.g. Loughlin et al. 2002a, Stevenson et al. 2013). Similarly, cases within the survey and the volcanology literature of participatory monitoring leading to enhanced relationships, trust and risk reduction are limited also. Instances of initiatives that continue over longer periods of time, which would create time and opportunity for trust to be developed between scientists and citizens, are also rare. Thus many of approaches used by the responding VMIs as currently designed and implemented are neither likely to: i) generate significant new knowledge, or; ii) facilitate risk reduction through enhanced relationships and empowerment, however experimenting with the collation and synthesis of data is a valuable part of the process towards achieving the aforementioned outcomes. Furthermore, organisations developing participatory monitoring or citizen science activities as a means of enhancing public science education are well known, but this often requires significant effort (Bonney et al. 2009) in terms of resource, and the pitfalls of using public engagement as a means of enhancing public trust should be considered (Wynne 2006). There are however some successful initiatives that are described in the survey, one of which is explored in great depth in Chapters 4 and 5.

The focus of the survey was on citizen participation in the monitoring of volcanoes, but in practice many of the initiatives have the potential to go beyond knowledge generation that can be used to reduce risk by fostering relational trust that enhances or catalyses risk reducing adaptations. The evidence here and in other fields suggests that long-lived, citizen-led or collaborative initiatives with systematic forms of monitoring are more likely to achieve these potential outcomes, as is the case from the responses of Alaska, New Zealand and Ecuador (where participatory monitoring is described in more detail in Chapter 4).

### 3.5.3 Are others facilitating participatory monitoring?

As noted in the introduction and in Chapter 2, a considerable amount of participatory DRR around volcanoes is carried out independently of volcano monitoring institutions. Many of these projects focus on empowering communities to plan and prepare for volcanic hazards in a risk management sense, but many of them also include community-based early warning systems. This can be very effective, but as described by Bowman and White (2012) when examining work around volcanoes in El Salvador, DRR projects that are not coupled with science or scientists can also be unsuccessful at stimulating risk reducing adaptations.

Of particular interest during the analysis of the questionnaire responses for this chapter, was a notable absence of any description of a community-based early warning initiative around Merapi, Indonesia, despite a response from the VMI there. The 'Jalan Merapi' or 'Merapi ring' (ComDevAsia 2011; Allen 2014) involves citizens communicating with each other via community radio stations and through twitter, about observations of volcanic hazards, namely pyroclastic density currents (PDCs), and organising evacuations. This network appears to function independently of official mechanisms involving authorities, volcanologists and civil defence. The observations of PDCs that are relayed, are partially derived from visual citizen observations, and partly repeated from scientific communications that are issued on the radio. This network is said by many to reduce risk considerably, yet it is not formally coupled with scientific monitoring efforts. When this issue was probed in follow up questions with a volcanologist from Indonesia, they seemed reluctant to comment much on the issue. In the future, an exploratory field-based study of this network is likely to provide considerable insight into the potential roles of citizen observers in risk reduction around volcanoes and the challenges of integrating this with formal risk management structures.

### 3.5.4 Adaptations

Evidence from a number of cases within the survey, such as Ecuador (thoroughly described in Chapters 4 & 5), at Alaska Volcano Observatory (Wallace et al. 2015), in New Zealand (working with Maori communities and tourists at White Island), and at the British Geological Survey (Stevenson et al. (2013), and 'myVolcano'), suggests that participation evolved out of a response to crises and shocks that they were not set up to respond to. These institutions, through necessity, were able to become reflexive in terms of how they learnt to learn how to improve participation, and thus have relatively clear rationales about why and how they do it. Many of the adaptations that the institutions made were as a result of experimentation and entrepreneurship, which is described by Stirling (2007) as an important process.

The majority of institutions are acting without much evidence of how to engage in successful participatory monitoring, emphasising the value of this global analysis and the need for more detailed analyses of existing approaches. Those VMIs that have seen successes have done so by adapting their processes with time learning in a reflective and reflexive way. In this way, it is possible to recognise that in many cases both advancing knowledge and developing relationships requires sustained participation, as has been demonstrated to be an effective approach in New Zealand and Ecuador. Analysis of the initiations of successful participatory monitoring initiatives around volcanoes, suggests that an amount of experimentation, creativity and entrepreneurship is also needed, not just for success but because of resource constraints, as suggested by a respondent:

> *"This work is valuable but in the scheme of priorities, comes out low on the list for funding and personnel attention. We have to get creative to make it happen."*

At the moment initiatives that have been sustained or are regarded as beneficial have often required a particularly adaptive individual or organisation to recognise the potential benefits of engaging with the public, and of participatory monitoring in particular. Pelling (2008) suggests that in the case of climate change, adaptations often occur in 'shadow spaces', as a result of informal interactions between those from different groups. Participatory monitoring could be conceptualised in a way where it makes use of these shadow spaces, and thus enhances or stimulates adaptations in the ways in which organisations and citizens interact. Indeed, as will be described in Chapter 4, some of the most critical risk reducing adaptations as a result of participatory monitoring are made in these spaces. The institutions that state tangible risk reducing effects of citizen science are predominantly those that have used it as a vehicle to foster relationships and community empowerment.

This analysis of participatory monitoring in volcanology on a global scale suggests that the potential benefits of engaging citizens in monitoring volcanoes continue beyond the usefulness of the data alone. Many of the successful initiatives have involved those institutions changing practice from 'business as usual' to adapt to an event or shock (e.g. New Zealand, Alaska and Ecuador), which is known to require institutional learning (Pelling et al. 2008; Field 2012). Evidence presented here suggests that other institutions, rather than continuing as they normally do, might want to consider the potential risk reducing impact of successfully collaborating with citizens ahead of future crises.

## 3.6 Conclusions

This chapter has investigated participatory monitoring, involving collaboration between volcano-monitoring institutions and citizens around many of the world's volcanoes. If carried out collaboratively by an adaptable institution, participatory monitoring has the potential to catalyse adaptations to risk, through the production of knowledge, more effective risk communication and by empowering communities to take or take part in risk reducing actions.

Many of the participatory monitoring approaches employed by volcano-monitoring institutions in the survey are scientist initiated, variously quantitative or qualitative, and extractive in nature such that citizens have limited involvement after volunteering observations or data. Initiatives that are short-lived or those that involve singular or limited numbers of interactions, appear less likely to contribute significant data sets, or engender empowerment or the ownership of issues as seen elsewhere by citizens involved in participation as community-based monitoring (Bonney et al. 2009; Conrad and Hilchey 2011; Stone et al. 2014b). However, either generating data that can be used for risk reduction or empowering citizens may not have been the intention of some VMIs, who see the development of relational trust through the process as one of the main benefits of participatory monitoring.

Many institutions expect benefits as a result of citizen participation in both knowledge generation and the development of relational trust. This is a common theme throughout the responses, though few initiatives are organised in a way that is likely to foster these benefits. Relational benefits of participatory monitoring are thought to require sustained participation through time, often with face-to-face interactions between scientists and citizens (Conrad and Hilchey 2011), factors that are not very prevalent in the survey responses from most institutions. From within volcanology and in other fields, there are considerable potential risk reduction benefits for those monitoring institutions that are required or expected to engage with citizens in risk communication, education or decision making, if they develop effective citizen science programs for use as a catalyst for developing relational trust.

Instances of new knowledge or research insights derived through participation are perhaps scarcer than they should be, considering the advances made in other contexts through activities labelled as citizen science. Some notable examples of citizen-derived insights into volcanic processes may act as an incentive for more investment and enthusiasm for participatory monitoring, along with institutions reflectively considering how best to achieve certain outcomes. As yet few initiatives have started with a deliberate initial design or taken advantage of new technology or sensors. Clearly, considerable potential still remains to be realised in exploiting new developments in cheap ground-based sensors or creating mass online databases.

A pervasive ad-hoc nature to many of the approaches described by VMIs in this questionnaire survey suggests that the majority are unlikely in their present state to generate substantial positive outcomes that most respondents perceive participatory monitoring to be able to facilitate. This is in part due to the relative infancy of many of the initiatives, under resourcing, and also as a result of limited intentionality in the design and reflectiveness in the application of them. This lacuna however, presents an opportunity for VMIs to improve the reach and effectiveness of their risk management activities through future initiatives.

Growing the body of evidence for positive outcomes of involving citizens in this way also has the potential to cause an upturn in the number of institutions prioritising participatory monitoring. Further study is also needed to understand the contextual controls that either open or close spaces or opportunities for participatory monitoring. Institutions that do not engage in participatory monitoring had a variety of reasons for not doing so, reflecting some ambiguity in the nature of the contextual controls governing participation. This in some cases may explain why some participatory DRR around volcanoes is organised by NGOs or researchers and de-coupled from monitoring institutions.

Detailed and contextually grounded descriptions of successful and unsuccessful participatory monitoring initiatives are likely to generate significant learning that can help inform volcano-monitoring institutions that want to develop these approaches, of which over half the respondents suggested they did. The following chapter will provide an in depth description of participatory monitoring, using a case study from Ecuador that is referred to in the responses to this survey.

# Chapter four

# Chapter 4: Risk reduction through community-based monitoring: the *vigías* of Tungurahua, Ecuador

## 4.1 Preamble

This chapter is taken verbatim from (Stone et al. 2014b), and reformatted for inclusion in the thesis. The journal formatted version of the paper is included in (Appendix A ). Author contributions are listed below the conclusions (4.9), but references have been moved to the main thesis bibliography, and acknowledgments, abbreviations etc. have been moved to the respective sections also.

At the end of the chapter is a post publication update (section 4.10). Within this update, are some observations regarding the impact of the published research and a return trip to Ecuador where the results of the study were discussed with *vigías*, scientists, and regional risk managers (4.10).

## 4.2 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.

## 4.3 Introduction

Volcanic eruptions rarely occur in total isolation, with over 600 million people living in areas that could be impacted by volcanic hazards (Auker 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 and Whiteford 2002; Kelman and Mather 2008; Wilson et al. 2012). Coupled with human attachment to place and community[1] (Dibben and 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 (Hicks and Few 2015). 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, when not informed by current scientific understanding, can have limited impact (Bowman and 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 and Fischhoff 2011; Fischhoff 2013). Thus, by framing the analysis of volcanic risk within the context of disaster risk reduction, 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 (UN-ISDR 2005; Maskrey 2011) and participatory disaster risk assessment (Pelling 2007). The views and knowledge of people at risk can help to shape future mitigation strategies (Cronin et al. 2004a; Maceda et al. 2009;

[1] The notion of 'community' has generated a large body of social science research, characterized 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.

Holcombe et al. 2011) and involving communities can also be a more effective way to manage hazards (Anderson et al. 2010).

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 and Hilchey 2011; Gura 2013). Studies in those fields have demonstrated that 'citizen scientists' can both provide good quality data (Parsons et al. 2011; Tulloch et al. 2013) 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. 2002a). 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 and Hilchey 2011).

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 fulfil 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.

## 4.4 Background

### 4.4.1 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 2007); 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 and Webler 1995), (ii) lead to better research outcomes (Holcombe and 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 (2001; Pelling 2007), (iii) consequently lead to distrust (Wynne 2006) and (iv) be nebulous and frustrating for the participants (Bowman and White 2012).

The involvement of communities has been firmly on the disaster risk reduction agenda since Hyogo, 2005 (UNISDR, 2005). Within the field of disaster risk reduction, participatory initiatives can include community-based disaster risk management (Maskrey 2011), community-based monitoring (Holcombe and Anderson 2010) and community-based early warning systems (Bowman and 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.

### 4.4.2 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* (Frewer et al. 1996; Poortinga and Pidgeon 2003; lang and priest 2007). 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. 2008b), 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.

### 4.4.3 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 (Ruiz et al. 2005; Fee et al. 2010; Le Pennec et al. 2011). 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 and Whiteford 2002), and lahars pose a persistent hazard even during periods of quiescence (Williams et al. 2008).

### 4.4.4 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 and 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 (Tobin and Whiteford 2002; Lane et al. 2003). 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 reoccupation, *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 4-1) by the Instituto Geofísico, Escuala Politécnica Nacional, Quito, Ecuador (IGEPN).

## 4.5 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 twenty-five *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 2012). 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 minimize 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 (Appendix C ). 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 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.

## 4.6 Origins and development of the *vigía* network

### 4.6.1 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 4-1). None of the *vigías* were formerly members of *Los ojos del volcán,* which disbanded soon after the reoccupation 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.

| Characteristic | Count |
|---|---|
| Gender | |
| Male | 16 |
| Female | 3 |
| Occupation | |
| Agriculture | 15 |
| Municipality | 2 |
| Education | 1 |
| Business owners | 1 |
| Drivers | 1 |
| Length of time as *vigía* | |
| 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 *vigía* | 1 |
| National Secretariat for Risk Management (SNGR) | 2 |
| Scientists | 4 |

**Table 4-1 Demographics of the *vigía* interview respondents**

Every night at 8pm, 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:

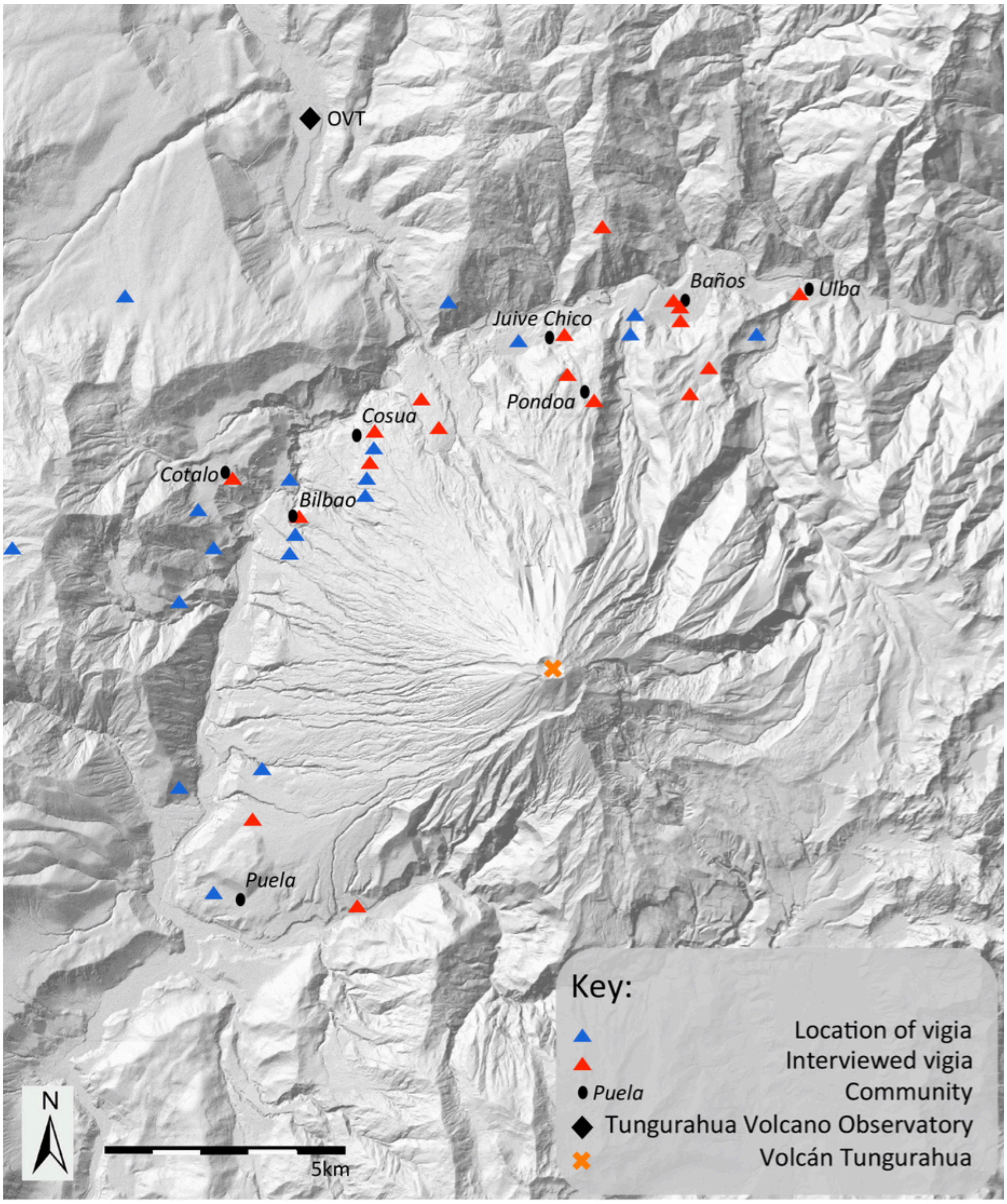


**Figure 4-1 Map showing the locations of *vigías* relative to the volcano, population centres and the volcano observatory.**

> *"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.

### 4.6.2 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 ash-meters at locations including the *vigías'* properties, which they maintained, to assist with the measurement of ashfall around the volcano (Bernard 2013).

### 4.6.3 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).

### 4.6.4 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 4-1). 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 prioritize supporting the network in the same 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.

### 4.6.5 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 8pm. 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 8pm 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* 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.

## 4.7 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.

### 4.7.1 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 and Hilchey 2011). 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 4-2), 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.”*

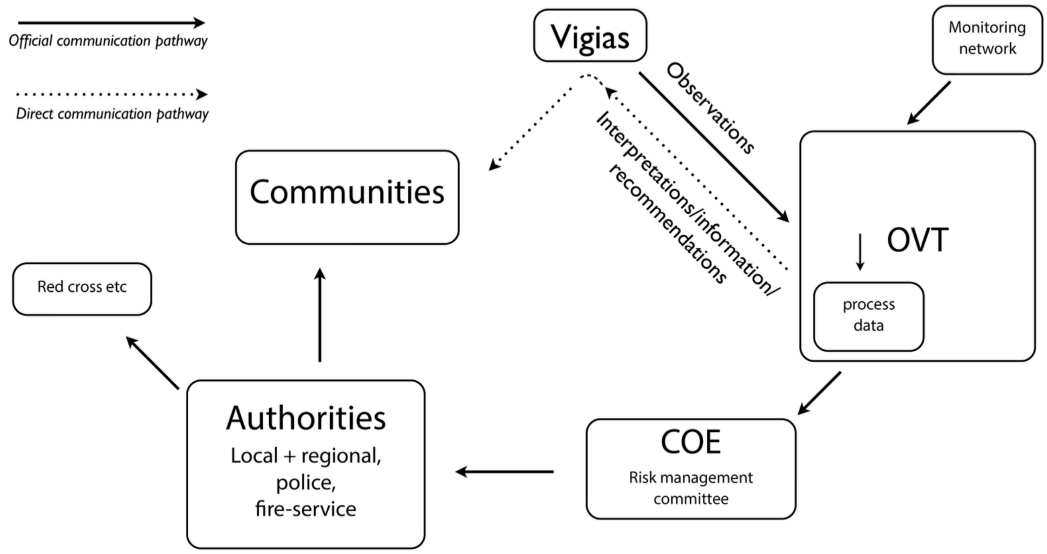


**Figure 4-2 Diagram showing the volcanic risk communication network, with the official pathway and direct (*vigía* mediated) pathway**

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 activity changing, 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 (Paton et al. 2008; Haynes et al. 2008b; Garcia and 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.

### 4.7.2 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 are or have become community leaders, are able to make a transition between volunteer observer and community-level decision makers 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 lead 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 4-2) 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 pre-empt official decisions and thus more quickly respond to changes in the level of risk.

### 4.7.3 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 reorganization 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).

### 4.7.4 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 fulfils 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. 2004a) 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 2007)). 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.

## 4.8 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.

## 4.9 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 & SCL contributed towards the discussion and reviewed the manuscript. PR & 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.

## 4.10 Post publication update

Following the publication of the paper, the vigías network has undergone a number of changes. At the time of interviews and analysis (May 2013-July 2014), there was some general disquiet as to the relative importance of the vigía network to SNGR (4.7.3). Since the research described here provided an independent analysis of the work of the vigías, this additional section reflects on the impact of these findings. Information about this impact has been gathered through informal note-taking during correspondence and discussion, and particularly draws on further informal conversations during a subsequent field visit in December 2014, as part of the STREVA Project.

Over this time period there has been a change in institutional behaviour at SNGR in relation to the vigías. This is attributed here to the increased attention to the vigías network following a concerted effort from IGEPN senior staff to seek funding for new equipment, this research, and the Strengthening Resilience in Volcanic Areas (STREVA project)

Following the publication of Stone et al. (2014), the vigías network was featured twice on the Nature website, once as a feature 'science soapbox' blog (Jackson 2014), and once in a news article 'World's deadliest volcanoes identified' (Witze 2015). The Science and Technical Advisory Group (STAG) for UNISDR invited submission of a vigías case study (Appendix D ) for their 2015 report on the use of science for DRR (Aitsi-Selmi et al. 2015), following a presentation about the vigías at a conference. This UN case-study (Stone et al. 2014a) had further traction in Ecuador, and was read by officials from SNGR (P Ramon 2014, personal communication, 14 December). The work was also written as a case study for supporting material to UNISDR GAR15 and subsequently published as a book chapter (Stone et al. 2015) (Appendix E ) These associated publications and online media were shared by IGEPN online and SNGR internally (P Ramon 2014, personal communication, 14 December), contributing to increasing awareness of the network and its importance to communities around Tungurahua. Following the initial STREVA workshop IGEPN scientists decided to publish their own reflection on their relationship with the community impacted by Tungurahua (Mothes et al. 2015, see acknowledgements) and this prompted further reflection of the value of this mode of working institutionally.

As a consequence of the experiential learning and positive impact of the *vigías* network, IGEPN sought to initiate another network at the Chiles/Cerro Negro volcano in the north of the country (on the border with Colombia) in October/November 2014 (interviews with IGEPN staff, December 2014). The volcano(es) had been experiencing seismic unrest, with numerous felt earthquakes. However, there has (at time of writing) been no eruptive activity there. The volcano is monitored from Quito, and the *vigías* only speak to scientists when they are in the field, instead communicating on a day to do basis with a locally based SNGR representative, meaning that at the moment, the network there has clear differences to the Tungurahua *vigía* network. Still in its infant stages, it remains to be seen how the network will develop, and is worthy of future study.

During the return visit with STREVA to Tungurahua in December 2014, the results of this research were presented and summarised to the *vigías*, IGEPN, SNGR and the regional governor in a formal meeting. The trip was very successful (M Ruiz 2014, personal Communication, 14 December), and the author presented the results of the research in Spanish at the meeting, and was encouraged to speak to the national press, along with IGEPN staff and another STREVA researcher about the work.

Six weeks after the workshop SNGR invested in new equipment for the *vigías*, including batteries, safety clothing and uniform.


**Figure 4-3 showing tweets by SNGR regarding the new equipment given to the *vigías* in Feb 2015**

This reinvigorated and positive 'institutional body language' from SNGR contrasts with the slightly flagging relationships during the time of the interviews (4.7.3). In personal communications IGEPN state that the important roles played by the *vigías* in the July 2013 and February 2014 explosions, combined with the impact of this research has driven this change in SNGR's policies towards community-based early warning.

Gathering tangible evidence for the impact of research of this nature can be problematic. In this instance, it is difficult to attribute the observed changes to any one of the factors described above in particular. Nonetheless it is clear that it was not just the execution and publication of the research alone that helped it to leverage positive changes. In this instance, continued engagement with the *vigías*, IGEPN and sharing the information with wider international processes, helped to convey the value of the network. Perhaps the difference between SNGR as described in Stone et. al. (2014b) and the current institutional attitudes towards the *vigías* can be illustrated by the exchange below between the author and the deputy director of SNGR, suggesting that supporting the *vigías* is (at least now) second nature to SNGR:

> *Author: "sirs – it is great to see you supporting the vigías"*
>
> *D-director: "It is our job to strengthen the system [@SNGR]"*


**Figure 4-4 Communication between the author and the deputy director of SNGR**

# Chapter five

# Chapter 5: A tale of two volcanoes: participatory monitoring through time and crises

## 5.1 Introduction

In the event of a volcanic eruption, early warning can reduce risk considerably (Garcia and Fearnley 2012; Winson et al. 2014) as a result of effective monitoring and communication that allows populations to reduce risk by limiting vulnerability and exposure to hazards. Thus, monitoring is an important driver for risk reduction around volcanoes. Evidence suggests that in practice, decreasing risk and increasing resilience to natural hazards requires collaboration between citizens, authorities, and scientists to design and implement locally relevant solutions that allow for adaptations to various shocks and stresses (UNISDR 2005; Pelling 2007; Gaillard and Mercer 2013; Djalante et al. 2013; UNISDR, 2015). Science and scientists have a vital role to play in the risk reduction process, contributing both to furthering the understanding of hazards and the provision of early warnings (Aitsi-Selmi et al. 2015) and so DRR is not only the domain of risk managers and citizens.

As demonstrated in the previous chapters, monitoring provides an excellent platform for citizen participation in risk reduction around volcanoes, but little work to date has investigated how and why participatory monitoring occurs in different contexts, particularly through the changes and adaptations that are made to various systems, such as social, political, economic, and risk governance systems, as a result of eruptive crises. In this thesis, the wide range of approaches that may be labelled ‘participatory’ have been discussed, before being synthesised into a new conceptual framework, that also incorporates approaches that are more usually associated with 'citizen science' alone. The findings from the survey of volcano monitoring institutions and their engagement with citizen participation presented in Chapter 3 suggest that whilst there is considerable potential for reducing risk by engaging with citizens in this way, there is perhaps no one ideal model of participation. They also identified that those institutions that had invested time and effort in these practices tended to be more positive about the outcomes. Chapter 4 then explores in detail a successful community-based monitoring initiative, analysing the outcomes for risk reduction, and the factors that led to its success and longevity.

Under dynamic conditions of risk, very little is known about the drivers for and barriers against participatory monitoring (Conrad and Hilchey 2011; Stone et al. 2014b). In particular, the interplay between the nature of the risk and its governance, and those collaborating in the participatory monitoring is not well understood. Addressing this gap in knowledge about the application of participatory risk reduction in complicated, often socially and politically charged contexts, is therefore of considerable value as it can inform future strategies to engage communities and citizens in risk reduction.

To build on the analysis of an initiative which is perceived to be successful by many of those involved in Chapter 4 (Tungurahua), this chapter takes a comparative case-study approach to compare and contrast participation through time with a second volcanic setting: Hills Volcano (SHV), Montserrat. Both volcanoes have had eruptive periods of similar length; varying forms and extents of participation in their monitoring; and there are substantial sources of information available for analysis, both collected by the researcher and in the research literature. In both cases, the volcanoes had (at the time of fieldwork) eruptive periods lasting for >10 years (since 1995 and 1999 for Soufriere Hills and Tungurahua respectively), with fluctuations in eruptive behaviour, and societal, governance, and scientific responses.

This chapter will introduce and describe the case-study contexts in some detail, but it does not aim to provide a definitive account of the events that occurred in either crisis; this can be found elsewhere (e.g. two special volumes on SHV (Druitt and Kokelaar 2002; Wadge et al. 2014a) and Tungurahua summarised in Mothes et. al. 2015). The aim is to use a crisis or series of crises at two different volcanoes as a conceptual lens to understand variations in participatory monitoring, including the forms of monitoring citizens are able to, or wish to, be involved in. There are considerable differences between the Soufrière Hills Volcano and Tungurahua (including the eruptive style, the progression of the crises over their current eruptive episodes, and the cultural, social and political contexts). Despite this, the drivers (and barriers) for participation, and the associated impacts that it is able to have on risk reduction, can be better identified and understood via this comparison.

Adaptations to participatory monitoring during both eruptive periods will be discussed, and a thematic analysis of evidence derived from interviews, other qualitative methodologies and published academic literature on the two crises, is used to identify the factors affecting the extent of participation and to unpick common drivers for or barriers against citizen participation in monitoring volcanoes.

## 5.2 Conceptual framework

### 5.2.1 Volcanic crises

The changes in participatory monitoring will be examined through different phases of 'volcanic crises' (Wilkinson 2015). A crisis is defined by UNISDR (2015b) as '*a threatening condition that requires urgent action*'. Wilkinson (2015) describes a volcanic crisis as a period of time that is characterised by a sudden increase in risk or impact, associated with various risk management actions. She identifies three main phases to a crisis: i) pre-crisis, ii) crisis (with a number of sub-phases), and iii) post crisis. (Table 5-1). Each phase has different implications for DRM (including DRR), representing phases in time when changes in different activities, systems, or processes might occur. Changes might be the establishment of early warning systems, which include monitoring, communication, and interactions between a number of actors (Garcia and Fearnley 2012). Other changes might include restricted access to certain areas, evacuations, re-occupations, and re-locations. All of these changes have implications for citizens who are affected by them or have roles to play in driving the change or adapting to it (Wilkinson 2015), such as evacuations, restricted land usage, or access to services and insurance (Lane et al. 2003; Hicks and Few 2015). Decisions that drive these changes require information or knowledge (Gaillard and Mercer 2013), much of which can come from participatory monitoring as shown in previous chapters.

This conceptual model based on 'phases of crisis' is not aspiring to account for or explain the development of participatory monitoring: rather it is an attempt to periodise in broad terms the different phases in the development of a crisis, over which the various changes in the roles of participatory monitoring can be overlaid. Transitions between each crisis phase are primarily based on an increase or decrease in risk, which might be because of a change in hazard, vulnerability, or exposure. At other times, the phases of crisis are not entirely driven by risk, but can be defined as lasting for as long as the types of risk management decisions (Table 5-1) normally taken during those phases are in place.

The separation between different phases of crisis is not always clear, as through a period of time there may be various crises (and phases of crisis), which may overlap if there is a short gap between eruptions. Further, the times where there is a change from one phase of a crisis to another often are not easily identifiable, as the changes are related to many processes and drivers that have multiple feedback loops (Wisner et al. 2004; Potter et al. 2014; Winson et al. 2014; Doyle et al. 2014; Wilkinson 2015).

| Crisis phases | Description | Risk management actions |
|---|---|---|
| **i) Pre-crisis** | Before unrest or eruptive activity | DRR mitigation actions, land-use planning, education, building resilient infrastructure, set up of early warning systems. |
| **ii) Crisis**<br>A sudden or marked increase in risk, which may be characterized in three phases: | | Various actions to manage and reduce risk to lives, livelihoods, and assets. Often accompanied by some kind of emergency response. |
| **a) Unrest** | A period of unrest caused by the movement of magma or fluids underneath the volcano. | A preparedness phase, upturn in monitoring capacity, risk communication campaigns, practice evacuations, risk management procedures updated.<br>Some risk management actions taken such as restriction of access/re-zoning of space. Set up of early warning systems. |
| **b) Start of eruption/new norm** | Where unrest turns into eruptive activity, magmatic or not. Or when the style of eruptive activity becomes the new norm. | Re-zoning of space, limited access, possible evacuations, changes in monitoring/forecasting |
| **c) Heightening of crisis** | Where the risk dramatically increases, because of changes in eruption (hazard) or changes in vulnerability/exposure | Normally accompanied by evacuations, either planned or reactive to an eruptive event. Entails some kind of emergency response such as food aid, non-food items, shelter. |
| **iii) Post-crisis** | Where either the eruptive activity declines or risk management reduces the risk significantly. Can often return to crisis rapidly. | Possible re-entry to evacuated zones, adaptations to reduce future risk such as permanent re-settlement, new risk governance arrangements, new land-use planning, restoration of infrastructure and livelihoods, adaptations to reduce risk from future crises. |

**Table 5-1 Phases of a volcanic crisis (adapted from Wilkinson, 2015).**

### 5.2.2 Responses to risks, shocks and stresses

Some of the drivers of change processes in the different phases of crisis can be described as or prompted by shocks and stresses to various systems (Wilkinson 2015). This typology of 'shocks and stresses' originates from the literature on resilience (Holling 1973; Klein et al. 2003; Twigg 2009; Mitchell and Harris 2012; Matyas and Pelling 2015), which describes an ability of a system to respond or adapt to risks, shocks, and stresses. This provides a useful conceptual understanding of what may be driving changes in crisis, implying four different but overlapping influences: i) risk, ii) shocks, iii) stresses, and iv) capacities to absorb, adapt, or transform (Pelling et al. 2014; Matyas and Pelling 2015).

Risk is conceptualised as a function of the likelihood of hazardous events, vulnerability and exposure of people, livelihood activities or assets (e.g. Stirling 1998; Twigg 2004; Wisner et al. 2004). Shocks describe the impact of hazards or changes to the social system, that are abrupt and usually short in duration, such as a hurricane or earthquake (Mitchell and Harris 2012; Matyas and Pelling 2015). Stresses are impacts that induce longer term pressures, such as long term change or degradation, as a result of multiple smaller shocks, such as the additional impact of lahar activity in the Belham River Valley, Montserrat, which has damaged infrastructure (Barclay et al. 2007). Stresses can also manifest as the pressure of extended high risk periods (Holling 1973; Mitchell and Harris 2012; Wilkinson 2013; Hicks and Few 2015). Both shocks and stresses can lead to temporary or permanent changes to systems. Capacities can be conceptualised in different ways (e.g. Twigg 2009; Pelling 2010; Pain and Levine 2012; Matyas and Pelling 2015), but generally describe the ability of individuals, communities, institutions, or systems to either absorb risks shocks and stresses, or make adaptations that remove or greatly reduce their impact. In this way, disaster risk management (including DRR and participatory monitoring) can be conceptualised as a set of activities that build capacities to enhance resilience.

Therefore, an understanding of resilience (e.g. Matyas and Pelling 2015) suggests that changes in any system as viewed through the lens of a crisis or multiple crises may at times be gradual before returning to a similar state (cope or absorb), may change incrementally and not return to a previous state (adaptation), and at other times the change may be quite sudden and irreversible (transformation). This means that participatory monitoring, which may be part of an early warning system or a knowledge production system for DRM, is likely to go through a series of changes during a crisis or number of crises, as a result of processes such as formal changes in terms of laws or new structures (e.g. those described in Montserrat by Wilkinson (2015) or as a result of social learning (Pelling et al. 2008).

### 5.2.3 Influences on participatory monitoring

Evidence presented in the previous chapters suggests that participatory monitoring is influenced by different factors. Chapter 2 sets out a series of rationales for participation in response to risk (e.g. Fiorino 1990; Stirling 2007) that describe how or why it may originate, and evidence from Chapter 3 then describes the ways in which participatory monitoring is predominantly initiated in response to a change in volcanic risk. Chapter 3 also sets out a case for the importance of volcano monitoring institutions in monitoring and forecasting risk, and building knowledge that can by used to identify and reduce future risk. Chapters 3 and 4 describe how risk governance (see Chapter 2 for description or UNDP (2013); Wilkinson et al. (2014)) has an effect on the opportunities or spaces for citizens to participate, and that relational trust between different actors is essential for participatory risk reducing outcomes. Chapter 4 also shows that successful outcomes of participatory monitoring build the agency of all actors to continue with it. Chapters 2, 3 and 4 suggest that the agency of citizens to participate in participatory monitoring and DRR more generally is of importance, and shaped in a number of ways, related the extent to which they are empowered or sufficiently enthusiastic to participate in monitoring processes. It is also known that the way participatory monitoring is framed has an affect on citizens empowerment or agency (Pelling 2007;

Haklay 2012). These different influences and factors will inform the thematic analysis of the two case studies in this chapter. The aim here is to understand the most important influences on participatory monitoring, and particularly those which transcend the particular geographical context.

### 5.2.4 Summary and chapter structure

This chapter will use the different phases of crisis as a framework to identify the points in time, events, or processes that drove changes in participatory monitoring between the two settings. As discussed above, the boundaries between different phases are loosely defined, and over the course of long eruptions there may be repeated phases, so the two absolute eruptive timelines, developed in the context of the monitored volcanic activity (Figure 5-1 and Figure 5-2) are also described below and will also be used to reference key changes back to points or periods in time where possible. These changes will be examined for contextual influences, varying in response to risks, shocks, stresses, and the development of capacities, through periods of eruptive activity at the two case-study volcanoes. This will be used to build an understanding of the drivers and barriers to participatory monitoring and its contribution to risk reduction in the two locations.

## 5.3 Methods

Examining how and why participatory monitoring has changed through two long-lived volcanic eruptions is complex, as a result of multiple factors, processes, and controls that affect participation, many of which are interdependent. A case-study approach is taken in this chapter to compare and contrast between two locations, to develop a greater understanding and awareness of the development of participatory monitoring. The research design takes a comparative approach between two critical cases (Yin 2003), chosen because of the longevity of eruptions and dynamic changes to participatory monitoring, with the benefit of longitudinal elements to both cases (Yin 2003).

### 5.3.1 Fieldwork

The fieldwork for both locations spanned several months. The work in Montserrat was carried out over two field seasons totalling six months in 2012, where the author spent time with the Montserrat Volcano Observatory and was involved in their outreach and education work with local schools (including some citizen science activities) and attended a Scientific Advisory Committee (SAC) meeting. The author conducted twenty-eight interviews with elites (politicians and senior civil servants), residents, scientists, former scientists, former participants (in participatory monitoring), risk managers, local school teachers, and current volunteers at the volcano observatory. Some interviews were also conducted with scientists and former scientists in the UK at other times. The interviews were to explore the central research questions around participatory monitoring, including when it had occurred, what outcomes had resulted from it and how it had changed through time. During one of the field seasons, the author was involved in a large workshop related to the STREVA project (STREVA 2015), which examined risk and resilience in Montserrat since 1995. The workshop was attended by many of those that the author had interviewed previously, including past and present risk managers, observatory scientists, current and former UK and Montserrat government officials, and citizens. The workshop did not generate data for this study, but the recorded discussion contributed to a deeper contextual understanding of the crises for the author, which helped with the development of the research questions for this analysis

The fieldwork in Ecuador comprised of one field season in May, June, and July 2013, and a return trip in December 2014. The author spent time (including field visits) with IGEPN (and the Tungurahua Volcano Observatory), and also made field visits with the Tungurahua Fire Service. For more detail on initial and follow up interviews, see Chapter 4. The author also participated in a STREVA workshop that was similar to the workshop in Montserrat, again facilitating focus group discussions with many of those who the author had interviewed previously or who were interviewed following the workshop, further developing deep background contextual understanding of the case study.

The focus on risk and resilience in the two STREVA workshops provided an opportunity for the author to develop a deeper understanding of participatory monitoring within the context of the various crises at the volcanoes.

### 5.3.2 Data collection methods

The mixed qualitative method approach was designed to develop insight, contextual meaning, and understanding from the perspective of a variety of sources. These methods (described in more detail in Chapter 4, and replicated for the Montserrat case-study), included: elite interviews, semi-structured interviews, ethnographic approaches such as participant observation and conversations with a purpose, and documents collected for analysis (Bernard and Ryan 2009). Interviewees were selected purposively (because they had previously been involved in or had a perspective on participatory monitoring) and through snowball sampling (where interviewees or others recommend who else to interview) (Bryman 2012).

All interviews were recorded where possible, with permission of the interviewee, using a digital voice-recorder. Care was taken where possible to mitigate against positionality bias (where an interviewee is inclined to modify their responses as a result of whom they perceive the interviewer to represent) particularly in Montserrat where the author had been a member of staff at MVO in 2009 and 2010. To do this, the author organised the interviews independently of MVO and made it clear to interviewees that he was an independent university researcher. In Ecuador, a local field assistant was used (also a geology student), to aid with interpretation and to help facilitate access to interviewees. Relying on a third party to transcribe and translate interviews is a potential source of error, but this was minimised as interview transcripts could be corroborated by the author's field notes and those of a STREVA researcher working around Tungurahua, who also checked the translations (as a fluent Spanish speaker). The research proposal underwent ethical review at the University of East Anglia and was conducted according to UK Economic and Social Research Council ethical guidelines (ESRC 2012).

### 5.3.3 Other data sources

This chapter focuses on a complex topic, which spanned a long period of time, therefore the author had to be aware of various biases, including positionality bias and hindsight bias (Tversky and Kahneman 1974) in the responses from interviewees. This is why it was particularly important to be able to triangulate between different sources such as the published academic literature on the eruptions and volcano observatory reports. This helped with fact checking and, where possible, tying changes in participatory monitoring to specific phases of the crises.

The chapter draws on published academic literature to unpick contextual influences at points during the crises. There is a wealth of academic literature on the eruption of the SHV (e.g. Druitt and Kokelaar (2002) and Wadge et al. (2014a)) and a smaller yet significant number of academic publications about Tungurahua (e.g. those referred to in Mothes et al. (2015) and Le Pennec et al. (2011)). Few of these, from either volcano, mention citizen participation in monitoring (with some exceptions (Aspinall et al. 2002; Mothes et al. 2015)), but many describe important aspects of the volcano monitoring institutions, the evolution of risk (including hazard, vulnerability, and exposure), changes in risk governance, and the impacts on citizens. The chapter also draws on reports from both observatories. The synthesised evidence tables (Table 5-2 & Table 5-3) detail the sources of the information that identify the occurrence of, or changes in, participatory monitoring.

### 5.3.4 Data analysis

The data were analysed by thematic analysis (Bryman and Burgess 1994; Bernard and Ryan 2009). With such a volume of information available, initial analysis work focused on the interviews and field notes from conversations with a purpose and participant observation that focused on participatory monitoring. The interviews were transcribed verbatim from audio recordings (where available) and from the author's supplementary hand-written interview notes, and then systematically coded (Bernard and Ryan 2009) firstly for the categories related to the four contextual influences identified from the other chapters and the wider academic literature: i) risk, or the risk context, ii) VMIs, iii) risk governance (and associated risk management), and iv) the agency of citizens to participate. This iterative process of coding meant that related topics identified in Chapter 2 such as citizen enthusiasm or motivations, risk management or disaster risk reduction, or those codes that emerged from the data during the analysis were then incorporated into the four broader themes where applicable. Further codes, such as learning, relational trust, and the importance of key individuals were also used. This coding approach was then used where needed for supplementary material from observatory reports and the academic literature. The original four contextual influences were evaluated for appropriateness against those emerging from the data and theory on participatory monitoring. Drawing on multiple sources in this way meant the findings could be triangulated (Denzin, 1970). These contextual influences and broader themes are listed in the synthesised evidence tables (Table 5-2 & Table 5-3), discussed in more detail below.

## 5.4 The Soufrière Hills and Tungurahua: background context and initial activity

Tungurahua is high in the Ecuadorian Andes and one of Ecuador's many active volcanoes (Hall et al. 2008). It principally affects the large town of Baños (population ~20,000) and surrounding areas (Lane et al. 2003); it is described in more depth in Chapter 4.

Soufrière Hills Volcano is on the island of Montserrat, a British Overseas Territory in the Lesser Antilles, and is the island's only active volcano (Young et al. 1998). SHV affected the (now destroyed) capital city of Plymouth (Figure

5-5) and resulted in risk management decisions that made almost two thirds of the island an off-limits exclusion zone (Donovan et al. 2012; Wadge et al. 2014b; Wilkinson 2015; Hicks and Few 2015). Montserrat is also a small island developing state (Pelling and Uitto 2001), which poses particular challenges for risk reduction, when compared to a larger nation like Ecuador, such as the potential for significant losses as a proportion of GDP from shocks or stresses (UNISDR 2015b).

From a volcanological perspective the Soufrière Hills Volcano and Tungurahua are considerably different in terms of eruptive history, styles of behaviour, and potential impact. Nonetheless, from a sociological perspective they may both be described as sources of threat for citizens who live nearby (Figure 5-4), and at the time of fieldwork had gone through similar durations of eruptive activity including several periods of 'crisis' over approximately 16 years: SHV 1995 – 2011 (Wadge et al. 2014b), and Tungurahua 1999-2015 (Mothes et al. 2015). In Ecuador, IGEPN identify twenty-two periods of eruption (Mothes et al. 2015; Figure 5-1) and in Montserrat five phases of lava extrusion are identified (Wadge et al. 2014b; Figure 5-2).

Both volcanoes have affected ways of life for citizens near and far (Tobin and Whiteford 2002; Lane et al. 2003; Donovan et al. 2011; Le Pennec et al. 2011; Wilkinson 2015; Hicks and Few 2015; Mothes et al. 2015) resulting in fatalities, loss of livelihoods, and migration. The two volcanoes have required and received considerable investment in monitoring (Aspinall et al. 2002; Ruiz et al. 2005; Donovan et al. 2013; Mothes et al. 2015). The eruptions have had significance beyond their immediate vicinity: both have a large and growing associated academic literature. The depth of knowledge generated in Montserrat is such that the understanding and analysis from these eruptions has been applied in many relevant settings beyond SHV (e.g. Aspinall et al. (2003), Sparks (2003), and Haynes et al. (2008b)).

This chapter refers to eruptive timelines to link changes in participation to key points in the crisis or eruptive behaviour. These timelines are reproduced and adapted from those published in papers that were in part developed through work on the STREVA project: for Montserrat – MVO (2013), and for Ecuador - Mothes et al. (2015). The timeline for Montserrat shows phases of lava extrusion and some monitoring data series. Other timelines are available for Montserrat which include more geophysical data (e.g. Wadge et. al. (2014b)). The appearance of the two timelines bears similarities, particularly the shading to denote 'phases' of eruptive activity (meaning times when lava was being erupted), used by MVO for communication purposes. This technique was shared with and adopted by IGEPN through the STREVA project (Mothes, personal communication, August 2013).

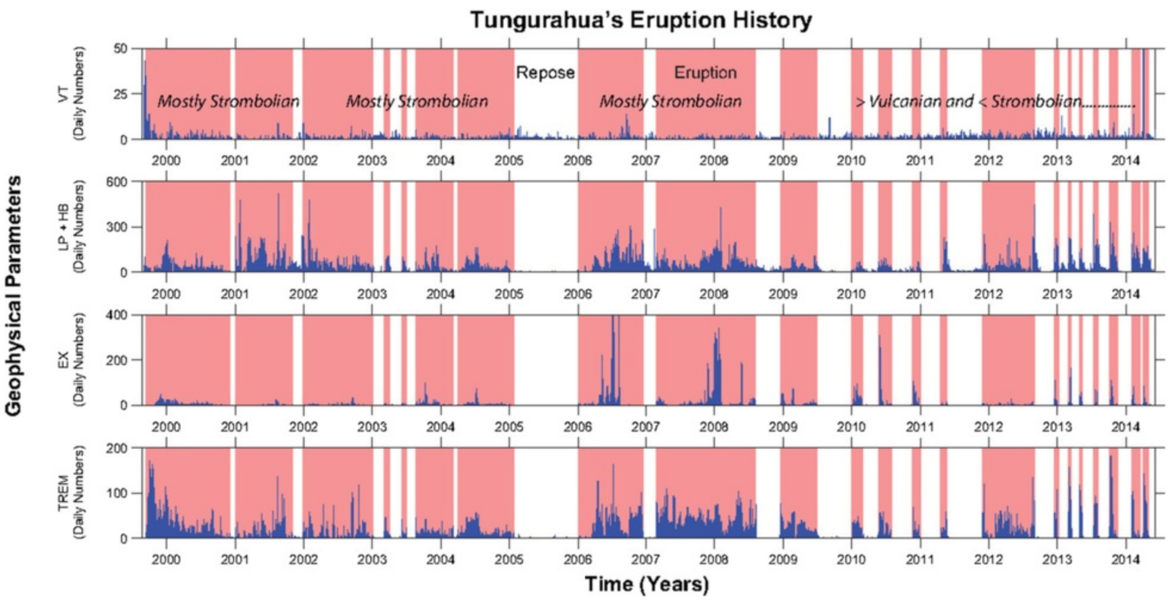


**Figure 5-1 A timeline of Tungurahua's eruptive activity 1999-2014, showing phases of eruptive activity, seismic event counts and explosions, adapted from Mothes et al. (2015)**

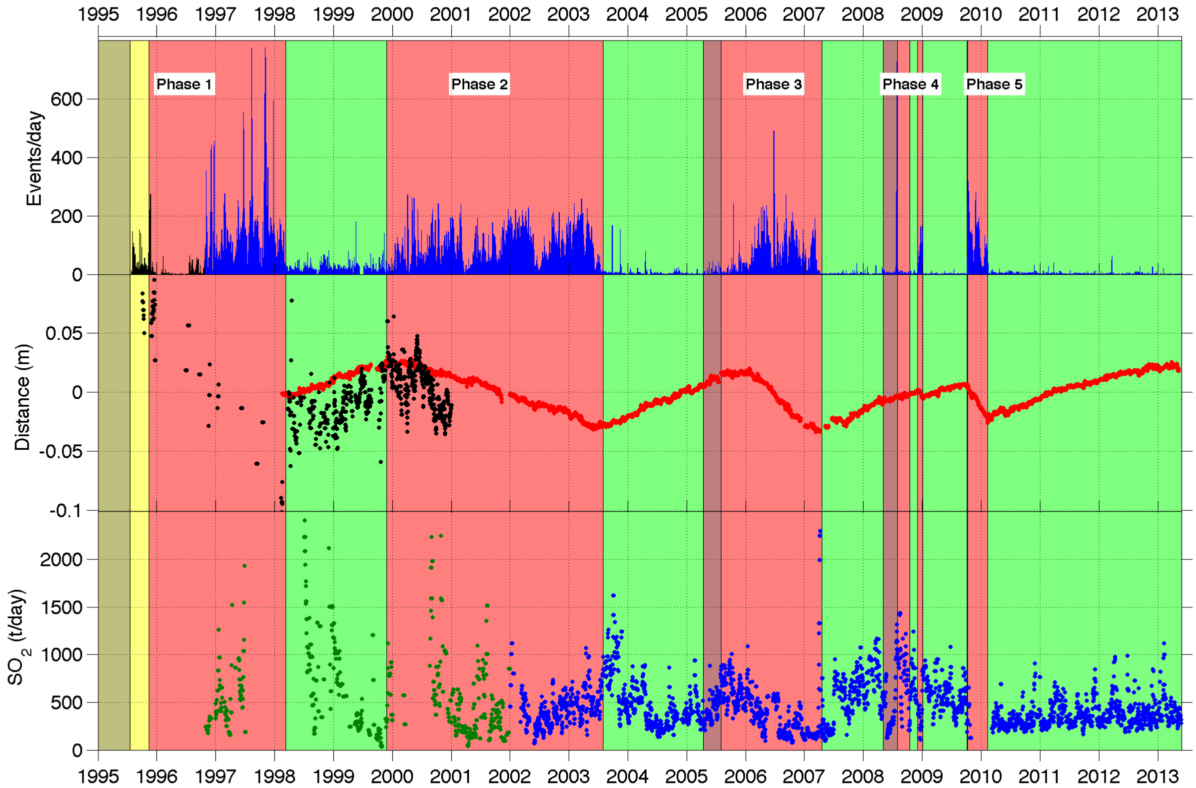


**Figure 5-2 A timeline of eruptive activity at the Soufrière Hills Volcano, showing phases of extrusion, seismic event counts, deformation and gas data, adapted from MVO (2013)**

### 5.4.1 Historical behaviour and pre-crisis

Eruptions from Tungurahua have been recorded in some form since AD1300 (Le Pennec et al. 2008), previous eruptive episodes had impacted citizens as recently as 1918 (Hall et al. 1999), and as such are very much embedded in the cultural memory of those that live there. For example, in the church in Baños there are numerous paintings depicting various eruptions, some of which caused considerable damage and/or loss of life (Figure 5-3).

**Figure 5-3 : Paintings in the church in Baños showing eruptions, with the bottom photo showing pyroclastic density current deposits in Baños**

The eruptive history, and indeed the associated cultural memory of eruptions at SHV, is considerably different, with the last known eruption in 1550 (Siebert et al. 2010). The eruptive history of SHV was relatively unknown or at least not talked about by the majority of citizens in early 1995 (although all knew of the active geothermal system which the name 'Soufrière' describes), despite the potential for volcanic activity having been the subject of several scientific papers and reports (Wadge and Isaacs 1986; Wadge and Isaacs 1988), one of which was a report submitted to the Government of Montserrat before 1995.

At both volcanoes, detailed and accurate geological mapping (and threat assessment to some extent) was carried out several years before the onset of new activity (Wadge and Isaacs 1988; Hall et al. 1999). In both cases, it was based on these reports and the understanding that they synthesized, that initial hazard assessments and risk management decisions were partly based.

According to knowledge gained through geological research and the current eruption, SHV erupts magma of typically andesitic composition and normally produces lava domes, with associated collapses and periodic explosions (Druitt and Kokelaar 2002). Eruptive behaviour and geological history of Tungurahua is described in Chapter 4 and thus not repeated here.

### 5.4.2 Initial stages of unrest and eruption

In Montserrat, there had been several seismic crises related to the volcano in the preceding years, some of which were powerful enough to cause damage to buildings (Shepherd et al. 1971; Stone 2012). Similarly at Tungurahua, IGEPN had been working on the volcano for some years, but started deploying a network of instruments following unrest months before the October 1999 start of accelerated unrest and eruptive activity (Mothes et al. 2015).

The two eruptions started and progressed initially in broadly similar ways. Both had a period of unrest, with elevated seismicity and changes to geothermal systems as a result of magma rising beneath the volcano (Tobin and Whiteford 2002; Mothes et al. 2015; Young et al. 1998). In both cases the onset of eruptive activity was in the form of phreatic explosions, progressing to erupt juvenile magma within weeks (Figure 5-4). The styles of initial magmatic eruption were however quite different: Tungurahua was mildly explosive, whereas SHV started to erupt a small lava dome. These initial styles are factors that had an effect on initial risk management decisions made by the respective authorities, and at this stage the ways in which risk was governed or managed diverged considerably at the two volcanoes (Mothes et al. 2015; Aspinal et al. 2002).

### 5.4.2.1 Evolution of monitoring institutions

At the very start of both eruption periods, neither volcano had a dedicated volcano observatory in close proximity. However, both had remote monitoring institutions; at SHV the monitoring was carried out by SRU (the Seismic Research Unit of the University of West Indies, now known as the Seismic



**Figure 5-4 Soufrière Hills Volcano (top), with Salem and MVO in the background right, Tungurahua (bottom), with Baños in the centre background. Author's photos from December 2009 and December 2014 respectively.**

Research Centre (SRC)) and at Tungurahua by IGEPN (see Chapter 4). As the respective crises developed, formal volcano observatories were set up at both volcanoes. The institutions and how they were organized are described in depth by Aspinall et al. (2002), and Donovan et al. (2013) for SHV, and by Mothes et al. (2015) for Tungurahua. They are further discussed here in relation to how they opened or closed spaces for citizens to participate in monitoring.

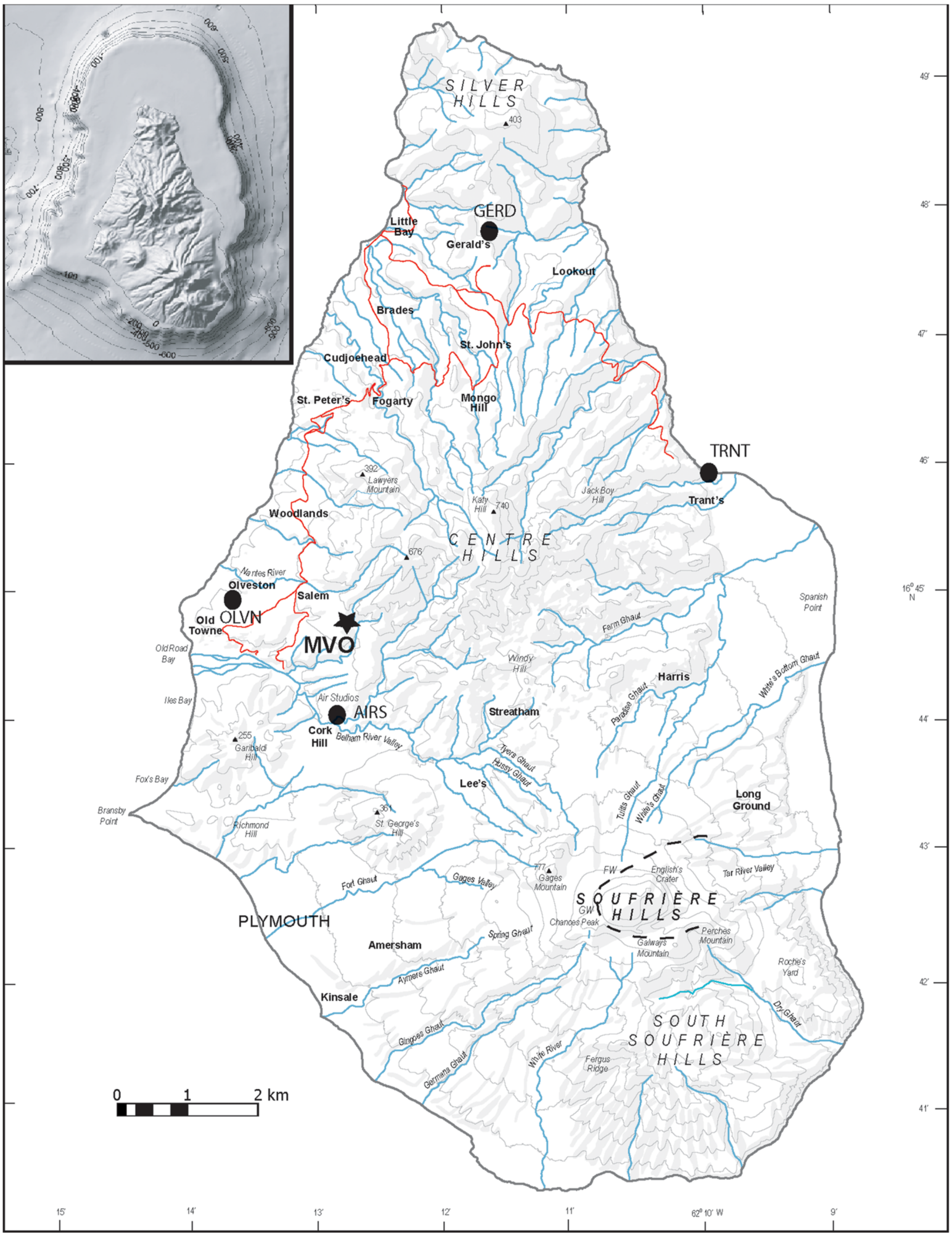


Figure 5-5 Map of Montserrat, adapted from Wadge et al. (2014)

In Montserrat, the initial monitoring arrangements were complex, with Seismic Research Unit, British consultant volcanologists, and the USGS VDAP team working together to monitor the volcano (Aspinall et al. 2002; Donovan et al. 2013). As the crisis intensified, the monitoring was formally run by the British Geological Survey, with the new MVO hosting a team of UK and international scientists. MVO stayed under BGS management until 2008, when the contract was taken over by the Seismic Research Center at the University of West Indies, and the *Institute du Physique du Globe de Paris* (IPGP) (Donovan et al. 2013).

#### 5.4.2.2 Initial public response

Without an eruption in 'living memory' some citizens in both areas reacted to the initial phreatic explosions in similar ways, with expressions of fear and uncertainty during interviews. Indeed, residents of the large town of Baños likened the initial phases of the eruption to life as depicted in the film 'Dantes Peak' (IMDB). In both crises, the combination of the uncertainty, risk management, styles of risk governance, and the physical impacts of the prolonged crises challenged ways of life for those there (Lane et al. 2003; Donovan et al. 2011; Le Pennec et al. 2011; Hicks and Few 2015). Maintaining positive relationships between scientists and citizens, where trust in scientific advice and associated risk management actions waxed and waned throughout the two eruptive periods, was also challenging (Haynes et al. 2008b; Mothes et al. 2015; Stone et al. 2015).

#### 5.4.2.3 Initial risk management / Governmental response

In both crises initial responses in terms of risk management decisions were based on understanding derived from past geological mapping, and varying governmental and scientific experiences of past crises at the volcano or volcanoes elsewhere.

Donovan (2013) and interviews with senior scientists (during fieldwork for this study) suggest that responses to the crisis in Montserrat were in part informed by previous eruptions experienced by the diverse team of scientists. For example, the regional eruptions on Guadeloupe (in 1976), St Vincent (in 1971 and 1979) and, for the USGS VDAP team the eruption of Mount Pinatubo in the Philippines (in 1991), influenced initial scientific advice and subsequent risk management decisions. Thus, from the start in Montserrat, the different perspectives and experiences of the monitoring scientists added to the uncertainty as to how the eruption might progress (Aspinall et al. 2003).

The risk from SHV was initially managed using micro-zones of access to land, produced from hazard maps of the volcano, based on threat to settlements or access routes to certain areas, and updated with new developments in activity (Aspinall et al. 2002). This created a situation whereby responses to increases in activity often then prompted a recommended evacuation or rezoning (Aspinall et al. 2002). Especially in the early months and years of the crisis (before the June 25th 1997 event), people were living or working in areas that could be threatened by hazards and so the observatory was manned 24 hours a day. Additionally, once Plymouth was fully evacuated (April 1996) the only way on and off the island was through the airport, which was situated on an old pyroclastic fan to the north east of the volcano. It was decided by the authorities that keeping the airport open was important (Hicks and Few 2015), and this further placed a strain on the scientists' time because this was only made possible by a scientist being permanently stationed there (various interviews).

At Tungurahua, knowledge of previous eruptions at the volcano, and the damage that they caused to Baños and the surrounding areas (Hall et al. 1999) meant that initial responses were influenced by a real concern for the potential of a large number of fatalities (Mothes et al. 2015). This meant that with the onset of phreatic activity, the President of Ecuador issued the order for a complete and militarily enforced evacuation of Baños and the surrounding areas (Lane et al. 2003). This evacuation lasted for 3 months, and was not popular (as elaborated on in Chapter 4), especially when the destruction of

Baños did not subsequently occur (Mothes et al. 2015). Thus, in the initial stages it could be argued that risk was managed in a more command and control style (see Chapter 2) than in Montserrat.

## 5.5 Participation through time

This section will describe the evolution of, and changes or adaptations to, participatory monitoring at each volcano. This will be described through the lens of the different stages of volcanic crisis, as identified in 5.2.1, with references to the two eruptive timelines (Figure 5-1 and Figure 5-2). As such the description of the changes will progress with time initially as both volcanoes progress through to a heightened crisis. Then both locations go through different series or cycles of overlapping crisis phases, and chronological progression in the description of changes becomes less germane. The objective of this way of presenting the evidence is to identify the main contextual influences present at different stages of crisis, to analyse what processes are driving change in participatory monitoring. Each section will reference the influence themes (described in 5.2.3) that may have contributed to change in participatory monitoring. As discussed in Section 5.3, evidence was derived and analysed from a large amount of information from multiple sources. Thus, a synoptic evidence table is used for each case study to present evidence of changes in participatory monitoring. The data in Table 5-2 and Table 5-3 contain information about the phase of crisis to which they primarily relate, with reference to eruptive activity, and the dominant influence themes at the time. The evidence within the text will refer to the table, original sources (i.e. interviews or published academic literature) the eruptive timelines (Figure 5-1 and Figure 5-2) and illustrative quotes will be used verbatim. Chapter 4 should be referred to for a more detailed description of the *vigías* network, however the data from Ecuador are analysed further here to provide direct comparison to the Montserrat case-study.

### 5.5.1 Participation in the unrest phase

As noted in Chapter 4, at Tungurahua, the only involvement of citizens in initial monitoring was via the provision of land and access for the placement of equipment. In contrast, an initial driver for participation in Montserrat at the beginning of unrest before the commencement of magmatic eruptions, was the lack of scientists on the island: the first to report mudflows in the Tar River valley (Druitt and Kokelaar 2002) were citizens, and when scientists from the SRU did arrive, volunteers and citizens seconded from other government funded roles (i.e. police or fire service) helped them in the field to set up instrumentation.

### 5.5.2 Participation at the start of eruptive activity (crisis phase ii b)

Early on in Montserrat, two officers were seconded from the police department to assist personnel in the field (various interviews). They can be understood here as citizen scientists because they were non-professionally trained scientists, who helped deploy and install instruments, and made observations. They were still paid for the Montserrat Government as members of the police force (and occasionally resumed duties there) but evidence from conversations with a purpose suggest that they worked with scientists in their free time too, in a voluntary role that transcended their secondment. This was some of the only participation at the start of the eruption of SHV, where evacuations in April 1996 (Druitt and Kokelaar 2002) signify an intensification in the crisis according to the framework in 5.2.1.

In Ecuador, initial eruptive activity prompted an evacuation, which arguably describes the eruption moving to heightened crisis phase, so there was no participation in the start of the eruptive activity (crisis phase ii b, see Table 5-3).

*Ecuador*

| Event/Change | Impact on participation | Evidence type | Influence theme | Additional influence | Possible crisis stage | When? | Positive or negative change |
|---|---|---|---|---|---|---|---|
| Establishment of monitoring network | Relationships built with some who would be vigias in the future | Interview | Relational trust | | Pre-crisis | Pre 1999 | + |
| Enforced evacuation | Formation of 'eyes of the volcano' (ojos del volcan - not actually participatory monitoring in the sense of the thesis). | Interview | Risk governance | | Crisis (start of eruption) | 1999 | - |
| Mistrust of scientific advice | Citizen monitoring in form of 'eyes of the volcano' was subversive rather than participatory | Interview | Science/population relations | | Crisis (start of eruption/new norm) | Various | - |
| Re-occupation | Many people living in high risk areas and in need of early warning | Interview | Risk governance | | Crisis (heightening of crisis) | 2000 | + |
| People living in high risk areas | High risk and need to reactive evacuations generated need to observe volcano | Interview | Risk context | | Crisis (heightening of crisis) | 2000 | + |
| Mistrust of scientific advice | Imperative for engaging with communities | Various | Science/population relations | | Crisis (heightening of crisis) | Various pre 2006 | + |
| Difficult volcano to monitor, people living so close that it was hard to see everything at once on timescales needed for evacs | Scientists asked citizens for observations of activity | Interview | Monitoring institution | | Crisis (heightening of crisis) | 2000/2001 | + |
| Investment in network by Civil Defence | Radio network + handies allowed people to participate + encouraged it | Interview | Risk governance | And evidence of success | Crisis (start of eruption/new norm) | Various | + |
| Successful monitoring of lahars | Value of participation encouraged the recruitment of more vigías near lahar channels/investment of motorbikes | Interview | Sucuessful outcomes of participation | | Crisis (start of eruption/new norm) | 2002 onwards | + |
| Key individuals | Prioritise participatory monitoring, affect institutional culture | Various | Monitoring institution | | Various | Various | + |
| Payment for cleaning of solar panels | Added value of participation, incentive for vigias and activities more embedded in OVT | Various | Monitoring institution | | Crisis (start of eruption/new norm) | Various | + |
| Successes in 2006 | Expansion of network | Interview | Sucuessful outcomes of participation | | Crisis (heightening of crisis) | 2006 | + |
| Deaths in 2006 | Expansion of network | Interview | Risk context | Risk governance | Crisis (heightening of crisis) | 2006 | + |
| Limited use of government resettlement schemes | People still living in at risk areas, so need for early warning persists | | | | Post-crisis | | + |
| Change from DC to SNGR | Reduction in resource | Interview | Risk governance | | Post-crisis | 2008 | - |
| Change from DC to SNGR | Less value placed on network | Interview | Risk governance | | Post-crisis | 2008 | - |
| Change from DC to SNGR | Reduction in identity | Interview | Risk governance | | Post-crisis | 2008 | - |
| Low changeover of staff at OVT | Strong relationships build up over time, facilitating participation | Literature | Monitoring institution | | Various | Over time | + |
| Evolution of CBDRR | More roles for vigías, hence network strengthened | Interview | Citizens | | Various | Over time | + |
| Change in activity to vulcanian explosions/rapid escalation | Increased value placed on the network | Interview | Risk context | | Crisis (heightening of crisis) | 2010 onwards | + |
| International attention to vigias | More valued | Experiential | Sucuessful outcomes of participation | | Various | 2013/14 | + |
| SNGR recognition of worth of vigías | Network invested in | Experiential | Risk governance | | Various | 2015 | + |
| Multiple eruptive phases | Continued activity prompts participation | Literature | Risk context | | Crisis (start of eruption/new norm) | Various | + |
| Ultruistic motivations of vigías | Continued and enthusiastic participation | Interview | Citizens | | Various | Various | + |

**Table 5-2 Collated evidence of changes in participatory monitoring in Ecuador**

### 5.5.3 Heightened crisis phases

The initial heightened crisis phases in both case studies have numerous similarities, along with inevitable differences, but can broadly be associated with initial risk management decisions to evacuate areas around the volcanoes. In Ecuador, there were anticipatory enforced evacuations of people in Baños and the *faldas* on 16th October 1999. Whilst these evacuations decreased risk from the volcano as a result of limiting vulnerability and exposure, the risk management decisions arguably do not simultaneously signify a transition to post crisis, whilst people are still temporarily evacuated. Indeed, many interviewees talk of the losses to livelihoods as a result of the three-month long evacuation, suggesting a crisis of some form, in agreement with Lane et al. (2003).

## *Montserrat*

| Event/Change | Impact on participation | Evidence type | Influence theme | Additional influence | Possible crisis stage | When? | Positive or negative change |
|---|---|---|---|---|---|---|---|
| Lack of scientists on island at start of activity | First data about mud flows came from citizens volunteering information | Various | Monitoring institution | Citizen agency | Crisis (unrest) | Jul-95 | + |
| Installing monitoring network | Volunteers needed to help move equipment in early stages - when this became a regular occurrence they were then paid…which obviously 'decreased participation'. The nature of the payment is unclear - it may gave been re-imbursment of expenses at times rather than payment. | Participant observation | Monitoring institution | Citizen agency | Crisis (start of eruption) | 1995 | + |
| Risk tolerance differences between scientists and citizens | First lava in crater observed by citizen - who had different attitude to/understanding of risk | Various | Citizen Agency | Risk context | Crisis (start of eruption) | 1995 | + |
| Heightened activity | Volunteers needed to help as field assistents | Interview | Risk context | | Crisis (start of eruption) | 1995 | + |
| Citizen photographers and videographers | Scientists actively engaged with people who were taking video | Various | Sucuessful outcomes of participation | Informal/volunteered information then sought | Crisis (start of eruption) | 1995 | + |
| Citizen photographers and videographers accessing dangerous areas | Scientists distanced themselves from this, and it became subversive | Interview | Monitoring institution | Citizen agency | Crisis (heightening of crisis) | Various | - |
| Microzonation | Reactive to volcanic activity - required everyone to work together | Interviews | Risk governance | Risk context | Crisis (heightening of crisis) | 1997 | + |
| Heightened activity | Volunteers needed for obs duties | Interview | Risk context | Institutional resource constraints | Crisis (heightening of crisis) | 1996 | + |
| Scientists recognise value of informally collected information | Scientists seek out people with observations | Various | Sucuessful outcomes of participation | Citizen agency | Crisis (heightening of crisis) | 1997 | + |
| Citizen observations of events on June 25 | Value of citizen observations and new scientific insights noted by scientists | Conversations with a purpose | Sucuessful outcomes of participation | Demonstrated value of citizen knowledge | Crisis (heightening of crisis) | 1997 | + |
| Decrease in risk following evac of Salem June 1997 | Less need for citizens to help in obs room, less demand for monitoring data, less incentive for participation due to less risk | Various | Risk context | Risk governance | Post-crisis | 1997 | - |
| Command and control style/Science knowledge owned by scientists | One way communication? Little participation in decisions (which are based upon science knowledge and advice). | Literature | Risk governance | Monitoring institution changes | Post-crisis | 1997 | - |
| Pauses in activity | Less to monitor? | Various | Risk context | | Post-crisis | 1998 | - |
| MVO contract increasingly commercial under BGS | Less time for scientists, less space for participation | Various | Monitoring institution | Citizen agency | Post-crisis | Unspecified | - |
| Volunteers become staff | No longer citizens participating | Conversations with a purpose | Monitoring institution | | Post-crisis | Various | - |
| Volunteers leaving the island to get training | No longer around to participate | Conversations with a purpose | Monitoring institution | | Pre-crisis | ? | - |
| Anticipatory/precautionary risk management | Evacuations ahead of dangerous activity - less need for community-based EWS | Literature | Risk governance | | Crisis (heightening of crisis) | 1998 | - |
| 2007 evacuation…long but - no 24hr obs because no-one living there | Because people evacuated, no need for additional volunteer support of monitoring | Interview | Risk governance | Monitoring Institution | Crisis (heightening of crisis) | 2007 | - |
| 2008 MVO management change | Big outreach and education drive, renewed sending in of information/photos by residents | Literature | Monitoring institution | | Pre-crisis | 2008 | + |
| New staff | Did you see it' - social media and webforms used to gather citizen obs from near + far | Experiential | Monitoring institution | Related to phase 5 activity | Crisis (start of eruption) | 2009 | + |
| Heightened activity | Persuasive form of risk communication using residents photos of activity | Experiential | Risk context | Monitoring Institution | Crisis (heightening of crisis) | 2009 | + |
| Website breaking | No did you see it | Experiential | Monitoring institution | Also - no activity | Post-crisis | 2011 | - |
| Researchers visiting and starting citizen science projects | Participation in monitoring of volcanic hazards encouraged for a short amount of time. | Participant observation | Monitoring institution | | Post-crisis | 2011 | + |
| Certain directors | Some actively sought info from citizens more than others | Interview | Monitoring institution | Sci/population interactions | Various | Certain times - probably not to be mentioned | + |
| Mis-trust of science encouraged scientists to talk to citizens and use their observations in risk communication | Participatory monitoring used as a means to restore or build relationships | Literature | Science/population relations | | Various | Occasionally | + |
| Staff type/priorities | Some staff placed a stronger emphasis on engaging with citizens through the medium of monitoring than others did | Interview | Monitoring institution | | Various | Throughout | + |
| Staff leaving | Less use of citizen info from social media | Experiential | Monitoring institution | | Various | Various | - |
| Key eruptive events | Observations from citizens sought | Various | Risk context | Institutional need | Crisis (heightening of crisis) | Various | + |
| Evacuated areas | Less volunteers for participation over time, due to reduction in numbers living near volcano (availability of volunreers) and less risk | Various | Risk context | | Post-crisis | Various | - |

**Table 5-3 Collated evidence of changes in participatory monitoring in Montserrat**

In Montserrat the management of risk during eruptive 'phase 1' (Figure 5-2) was more reactive to the changing nature of the hazard with time, where an increase in pyroclastic flow activity would result in a change of alert level and therefore an evacuation of one or several micro-zones (Aspinall et al. 2002; Donovan et al. 2012; Wilkinson 2015). These contrasting styles of risk management had different influences on participatory monitoring in Ecuador and Montserrat.

The escalation of activity in Montserrat, coupled with many people still living in high risk areas, meant that a lot of man-power was needed to not only monitor the volcano (Table 5-3) but to use that information to provide early warnings. The observatory was ready 24 hours a day to recommend changes in alert level and thus suggest evacuations, with volunteers able to provide some of this needed capacity.

In Ecuador, the risk to the population was reduced dramatically by the evauation, meaning that few people were living in exposed areas. At this time, there was citizen monitoring of the volcano (discussed in Chapter 4) by the 'eyes of the volcano', based at an informal campsite on a ridge above Baños opposite the volcano (Figure 5-4). Rather than 'participatory', interviewees described this as self-led citizen science, predominantly motivated by a deep mistrust of the scientists and the authorities, conducted in a subversive manner. Using Pelling's (2007) framework, this could be classified as entirely citizen initiated non-collaborative monitoring, making use of qualitative data in an empowering way. The risk management decisions and mistrust of the volcano monitoring institution gave little space for citizens to collaborate with scientists.

Forms of monitoring, not carried out in conjunction with the scientists, were also occurring in Montserrat. A growing problem during the emergency phase of the crisis was people accessing very dangerous areas and taking images and videos of eruptive activity, some of which could be sold to journalists, documentary makers and tourists. The scientists faced a tension whereby making use of the images would implicitly condone (for some at least) access to dangerous areas in the eyes of the public, yet the information collected in these ways was highly valuable**:**

> *"He [citizen] would say what he had observed – and show us footage. But MVO couldn't condone it, didn't want to encourage others to do it, but it was useful information." (Senior UK scientist)*

The dangerous nature of this form of participation occurred to some extent in the shadows, away from anything that was sanctioned or allowed.

During the initial heightened crisis in Ecuador, the forced re-occupation of Baños and the surrounding areas signified a momentous change in risk governance at Tungurahua, as described by a Baños resident and former member of 'the eyes of the volcano':

> *"Well we returned to Baños with strength in a struggle, leaving 1-2 dead, and signed an agreement with the government that if we returned, we would do so on our own account to live here."*

This change in or lack of formal risk governance and management, coupled with high risk to returning citizens (continued hazard and increased exposure) drove a pragmatic response to the situation, leading to the formation of a network of *vigías* (Chapter 4). There were needs simultaneously for early warning, observations for the scientists and information for concerned citizens. Communities were no longer able to depend on the state for risk management and there were conditions of mistrust between themselves, the scientists, and the authorities. This, along with continued activity, drove participatory monitoring through the *vigías* to provide early warning within communities. Recognising the value of such a network for managing evacuations, Civil Defence then invested in a radio network, facilitating the communication of information about activity.

Heightened activity (and therefore risk) continued in Montserrat, requiring the continuation of volunteers' participation both in the field and in staffing the observatory for night-time duties. Efforts were also made in 1996 and 1997 to recruit local technical staff, whose roles were to help identify and record earthquakes, process deformation data, and help with other monitoring duties. These volunteers received some training and were in some cases still school students. The benefits of volunteers extended beyond the data, as one senior scientist described:

> *"Those people [volunteers] then had a clear view of the uncertainties and the quandaries and ambiguities of the whole thing. They could see it was just not easy. The biggest contribution was that they broke down the 'them and us' dichotomy [between scientists and citizens]."*

The crisis further intensified in Montserrat, culminating in the June 25th 1997 'Black Wednesday' event, where 19 people died (Figure 5-2). The event had several impacts on participatory monitoring. Eyewitness accounts of the event led to new understandings of the eruption dynamics and placed value on citizen observations (Loughlin et al. 2002a; Loughlin et al. 2002b). The event was also a turning point in the management of the crisis (Wilkinson 2015) and the subsequent evacuation of many citizens, reducing the risk and the number of citizens living within sight of the volcano, along with the relocation of MVO to the north of the island, drove the *"petering out of volunteers helping with monitoring" (senior UK scientist).*

Other heightened crisis events such as the 2006 dome collapse, coupled with a director that valued citizen observations, again called for citizen observers to provide eyewitness accounts, as described by a participant:

> *"The first time I took pictures was with (director), who asked me one time if anything exciting happened over here to send pictures because it helps with their timeline of events."*

The start of phase 5 (Wadge et al. 2014b) also signalled a deliberate strategy from the MVO director to seek out and use images from at-risk citizens (e.g. Figure 5-6) for forms of persuasive risk communication (personal experience and observations). Also during phase 5, the emergence of social media drove new ways for citizens to participate, including the development of a 'did you see it' reporting procedure on the MVO website for eruption impacts (usually tephra, similar to the USGS 'did you feel it' (USGS 2015)) on the island and in the wider region.


**Figure 5-6: A citizen takes a photo of "MVO (white building centre) receiving ash for a change", before sending it to the director**

Heightened crisis phases also signified important periods for the *vigía* network. The real risk reduction strengths of the *vigía* network were demonstrated during eruptions in July and August 2006. This was mentioned by all interviewees as an acutely important time. Particularly during the 16$^{th}$/17$^{th}$ August 2006 eruption when *vigías* were credited with spotting the emergence of pyroclastic density currents and an evacuation was subsequently called saving the lives of many in the Juive Grande area (Chapter 4 & Mothes et al. (2015)). During the same eruption, the absence of *vigías* in Palitahua – where the fatalities occurred – was rectified following the eruption. During these heightened crisis phases, the *vigía* coordinated communication and 'unofficial' evacuations (Figure 4-2) developed in parallel to formal or official risk management structures. Further periods were identified in interviews, such as the explosions in 2010, 2013, and February 2014. Indeed, the large explosion on 4th February 2014, and other factors related to the promotion of the *vigías* successes (Chapter 4), prompted SNGR to invest in the network with new equipment and more formal recognition. This is a change that happened outside of the heightened crisis phase, but was prompted by risk reduction successes during a heightened crisis.

### 5.5.4 Crisis: eruption is the new norm

Much of the development of the *vigía* network occurred during and through regular and repeated phases of activity over time ((Mothes et al. 2015) and interviews), meaning that the risk to those living near the volcano rarely diminished to pre-1999 levels. Following the re-occupation of Baños in January 2000, the crisis didn't intensify to the same extent as at SHV in Montserrat, with Tungurahua producing smaller eruptions (in comparison), and in the first six and a half years there was an absence of pyroclastic flows (until July 2006). During this time, the *vigías*, in collaboration with the scientists, managed to successfully give early warnings of numerous lahars, helping to restore public trust in science advice (interviews with scientists and Civil Defence, and Mothes et. al. (2015)). These successes acted as a driver to continue strengthening the *vigía* network, and Civil Defence subsequently provided several *vigías* with motorbikes so that they could monitor more lahar channels.

This stage where the eruption, or different phases of eruption (Mothes et al. 2015) became the new norm, is characterised by incremental adaptations to the *vigía* network, and the evolution of CBDRR as the network and the empowered communities reduced risk from volcanic and non-volcanic hazards. These changes include the development of the radio network, sustained interactions between scientists and *vigías*, training and enhanced awareness. A *vigía* recognises the value of the system as an adaptation that enables people to live near volcanoes despite high risk:

> *"It would be good that other places in the world implement such a system for other volcanoes, and maybe it would work so the high risk areas are monitored 24 hours instead of completely abandoned."*

In Montserrat, the establishment of an exclusion zone (27$^{th}$ June 1997) and the subsequent move of MVO to the north of the island meant that risk from the volcano was significantly reduced (through reduced exposure), despite continuing activity, and citizens there were focussed on developing the north of the island and setting up their lives there. This could be described as a time where the eruption became the new-norm. The evacuations and more permanent relocation (Figure 5-2) resulted in a decrease in the necessity for volunteers to help in the field and reduced the number of 24 hour duties needed at the observatory. Additionally, a scientist describes extra monitoring capacity provided by visiting researchers:

> *"If you wanted someone to stay up all night – you got a PhD student to do it."*

The end of Phase 1 (Druitt and Kokelaar 2002) in early 1998 and the ensuing pause in lava extrusion until late 1999, signified a move to post-crisis (as defined in Table 5-1) and also reduced the need for extra staffing at the observatory. Over time at MVO, through phases of lava extrusion and pauses (Druitt and Kokelaar 2002; Donovan et al. 2013; Wadge et al. 2014b), a senior scientist describes that *"a more solid kernel of staff was developed"*, increasing the volcano observatory's capacity to do all of the monitoring itself. Similarly, considerable investments were made in the automation of many of the monitoring data streams and the installation of automatic early warning alarms: an increasing reliance on technological systems to monitor the volcano remotely from MVO north further depleted the need for volunteers (various interviews). By the time that MVO moved back closer to the volcano to a purpose built observatory in Flemmings (2003) many of the volunteers trained in technical data processing had become paid staff and MVO had sufficient capacity through management of BGS to monitor SHV without the need for volunteers.

Another factor upon which interviewees in Montserrat commented was the difference between directors at the volcano observatory through time, where some directors were very keen for the participation of citizens, and others were not, as described by the citizen who took the photo in Figure 5-6:

> *"I'd send other directors pictures once in a while, but they didn't seem too interested, so I quit doing that."*

Some directors are remembered for being "*unapproachable*". A senior UK scientist described MVO in this period as at times becoming closed up, legalistic, and business like, which reduced some of the spaces for participation. Changes like this were perhaps not permanent and reflected individual personalities as well as institutional changes, but some of these sentiments are repeated in other work (Haynes et al. 2008b; 2013). Some interview respondents interpreted the lack of engaging with citizens or asking them for eyewitness accounts or observations during these times, as a sign of the institution returning to the "*them and us*" days of the early crisis.

At these times, when the eruption at SHV was the new norm, the risk, in terms of risk to the lives of those that the volcano could impact, was effectively managed via successive evacuations and re-occupations of certain areas (Wilkinson 2015). This model meant that if risk were to intensify, then there could be an evacuation, followed by a reoccupation (Aspinall 2012; Wadge et al. 2014b). The effective management, from the point of view of the scientists and risk managers, suggests that there was sufficient capacity that volunteers were no longer needed, although a scientist suggests a slightly alternative view on the progression of participatory monitoring with time:

> *"What you can sustain for a month or two in the excitement of an emerging crisis, you can't sustain over years. There is a natural lifetime for it. Naturally it has to die back."*

Further changes occurred in Montserrat in-between times that were either eruption as the new norm, or post crisis, such as during 2008 when the management of MVO was changed to SRC and IPGP. There was an influx of new staff, including a renewed effort at outreach and engagement, which incidentally resulted in the author being hired for six months to develop MVO's scientific communication and outreach.

### 5.5.5 Post crisis

After the large eruption of Tungurahua on 16th August 2006, there was a period of 'post-crisis' change for the *vigía* network. As a result of the perceived successes of the network, Civil Defence drove a significant investment in the network and a large expansion as detailed in chapter 4 and described by a senior scientist:

> *"One of the opinions of (Civil Defence commander), at that time, was that the higher the number of vigías involved in the network, the best for the early warning system. Then he decided on his own to give radios to a lot of people and at the end we finished with something like 60 vigías."*

However, this expansion wasn't without its problems such as an overprovision of volunteers, misuse of the radio network for other purposes, less clearly defined roles, and after a while the number of *vigías* reduced to around 25:

> *"To say something we had more than 10 vigías in one single place like Cusúa. Some of the new vigías began to use the radio frequency for other purposes different to the initial objective which was the volcano information flow between them and the OVT." (Senior Scientist).*

Risk governance underwent changes in 2008, with Civil Defence becoming SNGR. Along with this change, the *vigías* were clearly no longer Civil Defence volunteers, and were not adopted into SNGR to the same extent. This is described by a vigía:

> *"It [Civil Defence/SNGR] has changed negatively with a new name, they closed down the office, and we were without a leader, many of the volunteers left. But the danger of a hazardous activity still remained."*

This change may have contributed to a reduction in active *vigías* following the expansion in 2006, although this may be attributable to an over provision of *vigías* at the time, exemplified by ten active in Cusúa at one time (as suggested above). What the change in risk governance did seem to do however is cause the *vigías* to lose some of their institutional identity. The network seemed to become its own organisation (Chapter 4) working for each other and implicitly for the scientists. However, the scientists were not and are still not willing to formally incorporate the *vigías* as volunteers for IGEPN for various reasons that were not fully articulated in interviews, but related to institutional structural constraints and the perceived trust related benefit of the separation between *vigías* and scientists (Chapter 4). These factors for some time made it difficult for the *vigías* network to continue as before, with limited resource and aging equipment. Many *vigías* talk about the importance of the network functioning even when there is no eruptive activity:

> *"Vigía doesn't have a specific meaning, because I have done search and rescue at least two times on the slopes of the volcano. The first time I went to rescue an engineer from [IGEPN] who had got lost, and secondly I went to rescue a foreigner who had been out of curiosity to photograph the active volcano, so I went at 11 at night with some friends who weren't vigías and we found the person at 6 in the morning. We were very nervous because we reached the rock where the volcano began (the upper cone above*

*~4200m). It can be said that a vigía isn't just waiting around for volcanic activity but is also helping whoever they can." (vigía in Cusúa).*

In Montserrat, the end of phase 5 in February 2010 and a change of staff somewhat curtailed the use of the 'did you see it' feature, and the use of citizen derived images for risk communication from the observatory. In 2012 as part of the exploratory phase of this PhD, the author was involved in developing a school-based citizen science programme where students participated in monitoring long term environmental change in the Belham River valley (SAC 2012). This, however, was not continued by MVO or incorporated into their long term education and outreach or monitoring plans, however, several of the student citizen scientists that participated went on to become paid interns at the volcano observatory in subsequent months and years.

## 5.6 Discussion

Previous sections have described the evolution of participatory monitoring at the two case-study volcanoes using the lens of the different phases of crisis that each went through. During these different phases, the nature or presence of participatory monitoring changed at both locations. This section will draw on an analysis of the two crises in Montserrat and Ecuador and the wider literature, to discuss how different contextual influences open or close spaces where participatory monitoring might occur. Drivers for and barriers against participatory monitoring, including what outcomes it may have, in the two case studies will be discussed.

### 5.6.1 Contextual influences on participatory monitoring

During the analysis, four contextual influences on participatory monitoring around volcanoes emerged from the data, original influence themes described in section 5.2.3 and Table 5-2, Table 5-3: i) The risk context, ii) VMIs iii) risk governance (including systems of DRM), and iv) the agency of citizens to participate. In addition to these interrelated contextual influences, the other chapters identify several cross-cutting issues, such as relational trust, learning and the importance of key individuals. Also, the perceived successful outcomes of participatory monitoring are identified as a key influence on future activities in Chapters 2 and 3.

Within each contextual influence, there are a large number of other important factors. For example, within the 'risk context' there are different factors related to risk, including: probability of a hazard, vulnerability and exposure. Some factors such as these may be shared across different contextual influences and can not be disentangled, so are not unpacked in detail here. Indeed, the evidence suggests that whilst the influences themselves can not necessarily be disentangled as they are interdependent, they are however sufficiently distinct to provide a useful focus of analysis (Figure 5-7).

At both of the volcanoes there were some periods where participatory monitoring flourished, and others where it diminished, was not able to exist, or existed only in a subversive manner. The analysis shows that the contextual influences (Figure 5-7) act in different ways and at different times, opening or closing spaces for participation. Through the phases of crisis at the two volcanoes, drivers and barriers can be identified, and understood as shocks and stresses to systems of participatory monitoring, within the contextual influences.


**Figure 5-7 Contextual influences on participatory monitoring**

#### 5.6.1.1 Risk context

A clear and important factor that drove participatory monitoring in both crises is the presence of some activity or hazards at the volcano that citizens can help to monitor. Although this observation could appear trite, it is nonetheless significant. Indeed, in some of the cases from Chapter 3, evidence suggests that the absence of much to monitor means that considerable effort is required to initiate, develop and sustain participatory monitoring. This is in agreement with evidence from other fields (e.g. Conrad and Hilchey (2011)).

Therefore, a high-risk period, where frequent and visible hazards impact into or near areas where people live and work is a driver for participatory monitoring, as suggested by a scientist in Ecuador:

> *"It only works if you have activity that captures their attention. So it's good to have activity, it's good to have a reason; you got to have, 'this is our focus point, this is why we're concentrating'."*

This was the case in both emergency phases of the two crises. For example, in Montserrat it was not a declining hazard that reduced the risk but rather the reduction of exposure due to evacuations that contributed to a reduction in (but not complete absence of) participatory monitoring after the evacuations in June and September 1997. With less risk, and less people living near at-risk areas, there was less of a need for volunteers. A reduction in activity after Phase 5 (February 2010) in Montserrat drove a further decline in participation, with MVO no longer using citizens' photographs and fewer reports on 'did you see it?'.

Whereas in Ecuador, the very presence of communities living in high risk areas that are frequently impacted by hazards continues (at time of writing) to drive a need for participatory monitoring and the wider risk reducing roles that the *vigías* fulfil. Of course, the risk context is not solely dependent on the extent and impact of volcanic activity, to a large extent it is dependent on the actions of citizens and most importantly the authorities in terms of the ways in which they chose to govern and manage risk. Despite periods of quiescence in Ecuador, as described in Chapter 4, the *vigías* have managed to remain active through the monitoring or management of other hazards or incidents, however a prolonged period of inactivity is likely to pose challenges for the network's longevity according to the evidence presented here.

#### 5.6.1.2 Risk governance (and management) context

In both of the crises, technocratic or command and control forms of risk governance and management significantly reduced the spaces or opportunity for participatory monitoring, which is consistent with findings in participatory DRR more generally (e.g. Scolobig et al. (2015)). In Ecuador this happened early on, where enforced evacuations and the removal of citizens from near the volcano limited not only the number of people available to participate, but crucially, the animosity at the time rendered most collaboration between citizens and scientists a real challenge. This is not entirely related to the risk governance context alone, and involves negative feedback between this form of risk governance and citizen agency. It is known that technocratic forms of risk management can reduce the agency of citizens (Mitchell 2012; Stirling 2007), thus limiting their ability or opportunities to participate (Le De et al. 2014).

In both of the crises there is evidence that during an emergency and reactive stage of a crisis, if there are not command and control forms of DRM, participatory monitoring is able to flourish. These forms of participatory monitoring in both case-studies were collaborative (Haklay 2012) and emancipatory (Pelling 2007). Positive changes in participation were not because of the risk governance structure alone, but related to a very real presence of considerable risk and characterised by everyone *"pulling together"* (senior scientist, Montserrat). As suggested by another senior scientist in Montserrat, this period of necessary collaboration may not go on for ever, and eventually monitoring institutions or risk management authorities may learn to cope with the activity. If that coping does not involve active roles for citizens at its heart, as was the case in Montserrat, then the spaces for participatory monitoring are inevitably reduced.

In Montserrat, risk governance transitioned to one of very low risk tolerance (Wilkinson 2015; Clay, 1999), resulting in a large exclusion zone and enforced evacuations of marginal areas (Wadge et al. 2014a), along with technical science driven risk assessment (Aspinall et al. 2003; Donovan et al. 2012; Wadge et al. 2014a), which both reduced risk and drove a reduction in participatory monitoring. Stirling (2007) describes technical dominated risk management as those that 'close down' spaces for participation.

In Ecuador, the authorities engaged with the citizens and formed the *vigía* network as an adaptation to the risk, and this resulted in a transformational change to the system of risk governance. The *vigía* network was about more than just participatory monitoring and early warning, but acted to empower citizens in communities to adaptively manage risk more autonomously. This

allowed the *vigías* to fulfil multiple risk reduction roles, beyond knowledge production and communication. Whilst
risk management institutional changes, from Civil Defence to SNGR, eroded the place of the *vigías* within more formal risk management processes, this now appears to have changed with SNGR recently commenting that the *vigías* are an integral part of their risk management system (Chapter 4).

#### 5.6.1.3 Monitoring institution

In both of the crises, the volcano monitoring institution has had a pivotal role in shaping the ways and times that citizens have participated in monitoring. The actions and mandate of a VMI can be considered a product of the staff that work in it, the behaviour of the volcano, and the risk governance context that it operates in. Therefore, it is important to understand a VMI in terms how it interacts with other institutions, organisations, and citizens, and its culture and ways of acting (Pelling et al. 2008; Djalante et al. 2012), as detailed further in Chapter 2.

An institution that values, encourages and sustains citizen participation is evidently more likely to have it. In both of the crises, the monitoring institutions went through several changes that had effects on the ways in which the institutions acted. A monitoring institution is likely, as all institutions are, to change and redefine itself numerous times through a crisis or series of crises (Donovan et al. 2013). It is also possible for an institution to become stuck in certain patterns of behaviour, acting in a ‘business as usual’ way. Changes or ‘business as usual’ impact the spaces for participatory monitoring. In the case of Ecuador, the ‘business as usual’ mode for IGEPN has been to prioritise engagement with the communities predominantly through the participatory monitoring of the *vigías*.

In Montserrat, changes in MVO, in terms of physical re-location to the north for a while, or increasingly “*business–like or legalistic management*” under BGS, shrunk spaces for participation later on in the crisis. Similarly, MVO became increasingly reliant on technological forms of monitoring, ample numbers of scientific staff, and funding for fieldwork such as the regular use of a helicopter. Thus, it could be said that MVO settled into a 'business as usual' mode whereby it perceived itself to have the capacity for doing all the monitoring without any help; so there was little extra knowledge that citizens could help to produce. Therefore, it was only occasionally that certain directors or staff recognised the benefits of involving citizens beyond knowledge production in the development of relationships and enhancing learning, and thus 'business as usual' at MVO normally meant that citizens did not participate in any monitoring processes.

An important facet of the two monitoring institutions in this chapter, along with monitoring institutions that responded to the survey in Chapter 3, is whether or not there are key members of staff who recognise the value of participatory monitoring and actively encourage it or coordinate it. In Ecuador, there have been the same two scientists in charge at OVT for most of the eruptive period. Both of the scientists prioritise participatory monitoring and thus the institutional culture within IGEPN is favourable for continuing this, with junior staff also valuing its potential, and considerable effort put into building and sustaining relationships, as described by a scientist:

> *"So, the vigías have generally had a really good relationship with us. And then secondly, we tried to keep that nurtured, we go round and talk with them, we try to have these meetings every 6 months, we're the only ones that really gets them all together, bring them out to eat somewhere."*

At MVO, there has been a far higher turnover of staff at all levels. Apart from a small number of scientists who encouraged and fostered participatory monitoring, MVO's culture since the initial emergency phase has not created much space for it. One citizen again talks about the importance of the director:

*"I see MVO as an institution, there are a lot of things that the director has no control over, but it does matter to me when a director changes. We keep getting some really good people…like now it doesn't matter because the volcano isn't doing anything, but when it is, you want people in there who you can trust and believe."*

The author's experience from working in Montserrat as a member of staff at MVO in 2009 – 2010 and then for periods between 2011 – 2013 as a visiting researcher, is that not only is the director important, but so are the staff responsible for engaging with citizens. During the above periods, there were six different people responsible for outreach and education, and three different acting or permanent directors (SAC 2012; SAC 2013). These staff, in addition to changing levels of volcanic activity, perhaps contributed to considerable swings in institutionally organised participatory monitoring initiatives. A senior scientist gives an opinion on how directors affect participation:

*"There were contrasts in directors partly due to personalities, (director x) in particular was not approachable etc. or engaging, (director y) was overworked etc."*

MVO has actively pursued other forms of participation not related to monitoring, such as forms of deliberation, but they would plot relatively low down on Arnstein's ladder (Arnstein 1969), which is described in Chapter 2. The evidence presented here confirms that key individuals, who prioritise and encourage participation and engagement, not only create spaces for it, but also inspire other staff to do the same, as shown elsewhere (e.g. Pelling et al. (2008)).

#### 5.6.1.4 Citizen agency

A considerable factor affecting the participation of citizens is their agency for involvement. As described in Chapter 2, the agency of citizens to participate in DRR is complex, related to dynamics of power (e.g. Gaventa (2006)) and the interaction of agency with social structure. However, put simply, citizens can volunteer to participate, be willing respondents for calls to help, have enthusiasm for lengthy and considerable involvement, or seek to participate in subversive ways; they can have individual or collective *power* (Lukes 2005; Chapter 2) to do participatory monitoring. In some cases, particularly where citizens feel especially empowered to participate, this will create spaces for participation, giving extra impetus for scientists to start or continue collaboration in this way, such as following the re-occupation of land around Tungurahua in 2000. Similarly, in some contexts such as those where risk management is particularly technocratic and thus citizens are not empowered to make their own decisions, it is known that not only is there less likely to be space for participation, but citizens are less likely to ask for or offer it (Chambers 2006b; Pelling 2007; Stirling 2007; Maskrey 2011).

Evidence from Ecuador suggests that after the re-occupation of Baños and the surrounding *faldas* the citizens had considerable agency, and this led them to collaborate with Civil Defence and the scientists as a pragmatic way to deal with the risk. Montserrat was a similar story in the initial intense crisis phase, however, with time, and certain factors such as MVO changing, areas being evacuated, and freedoms of choice being restricted by the ways in which risk was managed, citizens had far less agency and opportunity to participate in monitoring. It is also important to consider that the reduction in population in Montserrat (Hicks and Few 2015) will have reduced the number of those available, willing or enthusiastic to participate in monitoring. Not everyone around Tungurahua was a *vigía* and evidence in this chapter and Chapter 4 suggests that not all have the desire or attributes to be, therefore as a result of a smaller population in Montserrat compared to the Tungurahua area, it could be expected that there would be less participatory monitoring.

In both crises there were citizens involved in monitoring the volcano in ways that were subversive to the scientists and authorities. In Ecuador, citizens watched the volcano during the 3-month evacuation and then subsequently organised evacuation plans for Baños following the re-occupation, with the motivation of ensuring the town was not abandoned. Whilst not in direct confrontation with the scientists, it was fuelled by animosity between citizens and what they perceived were risk management decisions based on flawed science. In Montserrat, scientists not wanting to implicitly or explicitly condone citizens going to dangerous areas, intentionally kept the potentially valuable observations of some photographers and videographers at arms length. The citizens' collection of media at high risk was subversively affecting the scientists desire for reducing risk.

## 5.7 Conclusions

This chapter has analysed participatory monitoring through time using two case study volcanoes with long-lived eruptions, through the lens of different phases of volcanic crisis. This conceptual model suggests that eruptions may go through multiple and overlapping phases of pre crisis, crisis – including unrest, start of eruption, eruption as the new norm, heightening crisis – and post-crisis. Different phases are defined by risk management actions that typically occur during them and may transition from one to another as a result of changes in activity, incremental adaptations to risk management, or transformational changes to risk governance.

Participatory monitoring can be analysed during these different phases and the factors or contextual influences that drive changes in them can be understood. Drivers and barriers to the scope, extent and impact of participatory monitoring can be understood as shocks and stresses to the system, which itself may change incrementally or suddenly in response. The analysis of the two case-studies identified four interdependent contextual influences: i) the risk context, the risk management (and governance) context, iii) the VMI and iv) the agency of citizens to participate. Changes in these contexts through the different phases of crisis at both volcanoes impacted the extent to which citizens participated in monitoring and other DRR processes through time.

In Montserrat, initial participation, where citizens had numerous roles, decreased in response to increasingly technocratic forms of risk governance. Changes to the systems of risk governance and associated risk management decisions – namely evacuations which reduced exposure to hazards, thereby changing the risk context – closed spaces for participation. Sporadic participation occurred after this related to key eruptive events, consistent with findings in Chapter 3, and as a result of key individuals at the VMI prioritising it.

In Ecuador, initial risk management decisions reduced exposure to citizens, so none were living at sufficient risk for participation or invited to participate in monitoring. Fuelled by a deep mistrust of authorities and scientists, there were subversive forms of monitoring carried out by citizens on their own. Participatory monitoring in the form of the *vigía* network was born out of a dramatic change in risk governance. Here roles broadened over time, and the network showed itself to be resilient to shocks and stresses caused by risk governance and volcanic activity. A consistent drive for participatory monitoring from the VMI and few periods of repose in risk further drove participatory monitoring.

The findings from this chapter show the importance of these different contextual influences and important cross-cutting factors for successful and sustained participatory monitoring. They will be further discussed with respect to findings from the previous chapters in the following chapter.

# Chapter six

# Chapter 6: Discussion and Conclusions

## 6.1 Preamble

This chapter draws on the findings from the previous chapters, discusses and summarises the research conclusions of the thesis. Drawing on evidence from the literature and the findings of this thesis, the chapter presents a new conceptual framework with which to analyse the risk reduction potential of participatory monitoring initiatives. It describes the multiple roles of participatory monitoring in risk reduction around volcanoes making distinctions between short timescale disaster risk reduction and response, and longer term capacity building. It also provides new insights into the role that participatory monitoring processes can play in fostering trust between scientists, citizens and authorities, and the effect that this has on risk management.

## 6.2 The roles of citizens in DRR around volcanoes

The synthesis in Chapter 2 of the available academic literature demonstrates how citizens have important roles to play in disaster risk reduction. The evidence shows that not only do citizens have agency and capability to reduce risk (e.g. Twigg 2004; Holcombe et al. 2011), but that for effective DRR they should be at the centre of both risk management and reduction strategies, and involved with their implementation (Delica-Wilson 2005; Maskrey 2011; Lavell and Maskrey 2014).

The importance of knowledge in DRR is highlighted, as is the essential role of citizens in bridging gaps between knowledge and action (Cadag and Gaillard

2012; Gaillard and Mercer 2013). The monitoring of volcanoes is an important means of knowledge production (Sparks et al. 2012), and is critical for the early warning of hazards or impacts. Citizens can participate in these processes, interacting with multiple stakeholders across multiple scales. Participatory monitoring might involve collaborations between citizens, scientists, other stakeholders and science processes. Furthermore, participatory monitoring can occur at a wide range of spatial scales: from local or community-based activities, to the more dispersed activities associated with the remote sensing of data. To explore these participatory processes, learning can be synthesised from two broad fields of research and practice: i) participatory disaster risk reduction; and ii) citizen science. Scholars such as Pelling (2007) describe participatory processes such as PDRA, demonstrating the ways and dimensions in which participatory knowledge production processes can vary. Others, such as Haklay (2013) synthesise research from citizen science to demonstrate different levels, which are differentiated by the extent to which citizens design the initiative or own the results. This thesis demonstrates how these and other conceptual frameworks (e.g. Arnstein 1969; Funtowicz and Ravetz 1993) show that the generation of data and the outcomes of the participatory process are important in the production of knowledge, and are often shaped by dynamics of power between stakeholders.

These are important insights for considering the ways that participatory monitoring can contribute to risk reduction and are crosscutting themes in this chapter. This thesis focuses on the detailed analysis of participatory monitoring initiatives involving citizens and VMIs. Survey respondents in Chapter 3 did identify initiatives that were occurring between citizens and scientists who are not part of a VMI or the formal risk management structure of a given area, and the review in chapter 2 describes several examples of these (e.g. Cronin et al. 2004a; Gaillard 2008; Bowman and White 2012; Hicks et al. 2014; van Manen 2014; Allen 2014). Within these examples, non-VMI scientists may be university or research institute scientists, or staff from an NGO. From the available literature on these initiatives there are some parallels with the detailed findings described in this thesis but future work could, in particular, explore the impact that having ‘external’ or ‘non-local’ scientists has driving the success of participatory monitoring initiatives.

## 6.3 Risk reduction through participatory monitoring

As discussed in previous chapters, volcano monitoring institutions are of significant importance for DRR in volcanic areas and are well placed to collaborate with citizens to reduce risk through participatory monitoring. The global survey of VMIs (presented in Chapter 3) shows that two thirds of sampled institutions do some form of participatory monitoring. This participatory monitoring is initiated for different reasons with various drivers and barriers determining its contribution to risk reduction.

### 6.3.1 Initiation of participatory monitoring

Many of the participatory monitoring initiatives described by the survey responses in Chapter 3 were started in response to eruptions and the opportunity for data collection this necessitates. Those data were sometimes asked for from citizens by VMIs, and at other times were volunteered by citizens. The data collected were often in the form of qualitative observations (such as eyewitness accounts) or photographs. Some initiatives that started spontaneously in response to the need to collect eruption data have since become more formalised and have resulted in scientific publications with a focus on research rather than monitoring outcomes (Bernard 2013; Stevenson et al. 2013; Wallace et al. 2015). Other approaches, most notably the *vigías* network, started in response to conditions of high risk and a need for an early warning system (Chapter 4).

There is also evidence from the survey and the two case-studies in Chapters 5, that some of the key motivations behind VMIs creating opportunities for participatory monitoring arise from the benefits to relational trust that can be catalysed by these interactions. This desire from VMIs for citizens to trust them is also in part related to a need for more timely responses to risk communication and for VMIs wishing to legitimise their role in risk management. This motivation to stimulate trust was also frequently identified by the VMIs participating in the global survey in Chapter 3.

A recurring theme throughout the thesis is the importance of the agency that citizens themselves have to participate. Whilst agency is described in Chapter 2, in the discussion of Pelling's (2007) and Haklay's (2012) frameworks, as a key factor that determines the nature of a given participatory-monitoring initiative, the evidence from Chapters 3, 4 & 5 goes further to suggest that it can have an important role in the initiation. This is particularly evident in the nuanced links between citizen motivations to participate, and the spaces created by systems of risk governance for them to exercise their agency for DRR (Chapter 5).

### 6.3.2 Creating potential for risk reduction

The literature synthesis in Chapter 2 provides a strong argument for the importance of involving those at risk in the processes and decisions that act to reduce risk. This study of participatory monitoring in multiple volcanic contexts that experience a wide variety of associated hazards, has yielded evidence about factors that create the potential for participatory monitoring to stimulate risk reduction and to drive adaptations to risk. Whilst numerous key factors for successful participatory monitoring have been identified in the past, these depend on the theoretical framing or the desired outcomes of the work. This is described in Chapter 2. With respect to the reduction of disaster risk, several important drivers emerge from the thesis: i) The presence of risk, ii) a VMI that institutionalises participatory monitoring, iii) Risk governance that shares responsibility for risk management (as opposed to technocracy), iv) the motivations of participating citizens, v) the relational trust between actors and vi) the capacity that participatory monitoring initiatives have to adapt to different contextual influences. These different drivers will be discussed below. Additional sub-themes that affect the outcomes of the initiatives emerge from the analysis in this thesis. These are: learning (in terms of how participatory monitoring stimulates it or how those involved in the process learn to develop it), and the importance of key individuals for promoting or suppressing participation.

#### 6.3.2.1 The presence of risk

The presence of risk, or some perceived level of risk is a key driver for participatory monitoring around volcanoes, and the potential that it may have for risk reduction. Whilst it is contrived to observe that more risk results in more risk reducing potential, the evidence from Chapters 4 and 5 suggests that consistently elevated levels of risk, where times of reduced risk are limited, results in participatory monitoring initiatives that may build capacity to reduce risk.

The risk may vary as a result of hazard, vulnerability or exposure. Variations in hazard have an important impact on the participatory monitoring given that few initiatives exist where there is no observable hazard related to the volcano or the volcanic environment. Many VMIs in the survey responses that do not have current volcanic activity producing hazards, have rather less developed participatory monitoring initiatives.

Evidence from the *vigías* network shows that the repeated phases of eruptive activity over the course of the 15 years, described in chapter 5, strengthened the network's capacity to reduce risk through practice of reporting, emergency actions and a need for regular training. In Montserrat, pauses in eruptive activity were longer than at Tungurahua (Figure 5-1 and Figure 5-2), which may have slowly removed the risk driver. In both cases however, it was the marked reduction of risk as a result of evacuations (reducing exposure) that had a pronounced negative effect on participatory monitoring, due to less citizens living at risk, less need for 24hr monitoring and a reduction in citizen agency. Thus it could be suggested that the presence of a 'goldilocks' level of just enough, but not too much risk, creates potential for participatory monitoring to contribute to risk reduction.

#### 6.3.2.2 VMI institutionalising participatory monitoring

The initiation of many participatory monitoring initiatives around volcanoes has been prompted by eruptive activity, and organised in an ad-hoc manner. Chapters 3 to 5 demonstrate that institutions that have allowed or prioritised it as part of their operational practice, outreach activities and part of their 'monitoring culture', report greater risk reducing outcomes. This is true for outcomes related both to the development of early warning systems, relational trust and the generation of data for research (Bernard 2013; Stevenson et al. 2013; Wallace et al. 2015; Stone et al. 2014). Depending on the context, participatory monitoring can be institutionalised in different ways, and for different outcomes (Chapters 3 to 5).

#### 6.3.2.3 Sharing of risk management responsibility

Through the SENDAI Framework there is a globally directed desire for 'people-centred' DRR and DRM (UNISDR 2015), but in practice the extent to which this will vary may be according to the ways in which risk is governed in a given location. The different knowledge traditions that focus on 'participation' discussed in Chapter 2 – international development, disaster risk reduction, and science and technology studies – describe the benefits of sharing the management of risk with those who are at risk. In reality this equity is scarce, many at risk are informally 'empowered' to reduce risk because they have no state support to reduce risk for them (Oxley 2013; Scolobig et al. 2015). This thesis however, with its focus on participatory monitoring, shows ways in which risk management responsibility can be shared with citizens both formally and informally. Participatory monitoring initiatives in contexts where risk management is less technocratic (e.g. examples in Chapter 3 and the *Vigías*) have shown greater potential to reduce risk, consistent with arguments presented in chapter 2 (e.g. Stirling 2007). In this sense it could be argued that in contexts where citizens have choice to live in areas that have sufficiently high enough risk to prompt a need for mitigative or emergency actions, conditions are created where 'post-normal' science is required (Funtowicz and Ravetz 1993), necessitating VMIs to have a wider peer community.

#### 6.3.2.4 Citizen motivations for participation

The motivations of citizens to participate in monitoring determine much of the risk reducing potential that initiatives can have. Reviews of citizen science research have found that the curiosity, enthusiasm and dedication of participating citizens can result in high quality science (Conrad and Hilchey 2011), initiatives where citizens are curious and highly motivated like this have the potential to reduce risk in volcanic areas. Evidence presented in the thesis shows that some citizens who experience volcanic risk are regularly willing to voluntarily contribute intensive effort over long periods of time (strong dedication and sustained enthusiasm). The *vigías* often mentioned a sense of duty to their communities as their key motivation for participating, suggesting a normative purpose behind the network, and that the participatory monitoring serves as a vehicle for citizens with a strong sense of 'community duty'.

#### 6.3.2.5 Trust

A consistent theme throughout the thesis is the importance of trust between citizens at risk and scientists at volcano monitoring institutions. This is consistent with well-established findings (e.g. Haynes et al. 2007), and this thesis has shown how trust built through relationships as a result of repeated interactions over time between citizens and scientists even facilitates risk reducing adaptations amongst those outside of an initiative (Chapter 4). All of the responding VMIs to the survey in Chapter 3 identified the development of trust as a strong motivation for supporting participatory monitoring initiatives.

#### 6.3.2.6 Adaptive capacity of participatory monitoring initiative

The most successful examples of participatory monitoring initiatives have demonstrated capacities to adapt to changes in context. These adaptations involve both the citizens' roles, the VMI, and other risk management institutions, and response to differing hazard. For example, Stevenson et al. (2013) describe how BGS adapted to citizens volunteering ash samples by structuring a programme that allowed many to participate. In Chapter 4 it is shown that in Ecuador, the *vigía* network adapted incrementally through its lifetime, including times of large eruptions, periods of quiescence and changes in risk governance. In Montserrat, as described in Chapter 5 and elaborated on in following sections in this chapter, participatory monitoring there was not able to adapt to some transformational changes in risk governance, such as evacuations in Montserrat.

The six factors discussed above can be used to conceptualise different participatory monitoring initiatives and analyse the controls they have on the potential for reducing risk. To illustrate this, a conceptual diagram can be used to analyse the differences within and between initiatives (Figure 8). The evidence from the thesis suggests that progress or evolution of participatory monitoring does not necessarily follow linear or even simple trajectories, as a result of the large number of interrelated factors which influence it. An illustration of the two case studies from Montserrat and Ecuador have been plotted onto the model at three stages in time (from each eruption) to illustrate changes over time. This model came from the analysis of the previous chapters. At this moment insufficient data are available from the survey responses to confidently populate the diagram with more cases.

The scores for each axis are based on a preliminary descriptive evaluative framework (Appendix F). The scores and scales are nominal, illustrating relative differences between and within initiatives at different times. Larger scores represent a stronger positive influence from that driver so the area of each shape can be considered to be a proxy for the risk reducing potential of an initiative according to the findings of this study, if each driver exerts a similar degree of influence.

Using the different phases identified in Chapter 5, the two case-studies are split into three time periods: initial, early and late. The 'initial time' describes conditions at start of the initiative. 'Early' describes the first few years of the initiatives, in Ecuador – before the 2006 eruption – and in Montserrat before the 1997 exclusion zone. The 'late' time period describes participatory monitoring at the time of fieldwork.

Chapters 3, 4 and 5 demonstrate that high levels of risk make citizen involvement more likely, either through the occurrence of hazards to monitor, a need for early warning, or as a result of intentional relational trust building efforts from a VMI. The style of risk management affects not only the mandate of the VMI, but also the agency or opportunities that citizens have to participate.

In both cases, the agency that citizens have for participatory monitoring, the ways that the monitoring institution changes, and therefore the space available for participation, may vary as a result of adaptations to both the risk and risk management contexts.

### 6.3.3 Trajectories of participation

Two different trajectories or pathways of participation can be identified in Chapter 5 and Figure 8, which analyses two longitudinal case studies of participatory monitoring through time, that progress through two different pathways. Although both start with participation the end results are very different: in the case of Ecuador, the result is community-based monitoring, involving collaborative citizen science and participatory DRR. Whereas in the Montserrat case study, it is the institution itself that evolved over time to become a community-based monitoring institution, where citizens became members of staff. Evidence in the thesis and from Chapter 5 in particular, suggests that these two different paradigms of community-based monitoring are predominantly shaped by the different architecture of the drivers illustrated


**Figure 8 A conceptual model of factors that increase the risk reducing potential of participatory monitoring, with Montserrat and Ecuador examples at different stages in time plotted for illustration.**

in Figure 8, particularly the risk context and the style of risk management (as an associated product of risk governance).

### 6.3.4 Opportunities for participation

Despite changes that may occur in the risk context, risk governance and management context, institutions, or citizen motivations, evidence from Chapters 3 and 5 show that there are still opportunities for participation in DRM, even if it is not directly related to monitoring. As suggested throughout the thesis, it is important to not plan for an *'ideal form of participation'*, indeed, in different contexts participatory initiatives will take on different forms and have different outcomes.

It is important to consider how the disaster risk reduction benefits of participatory monitoring might be realised, despite various barriers against them (changes that can be made, how institutions or structures can support it, how citizens can be encouraged). It is also true that even in localities where forms of risk management are technocratic, empowering citizens to reduce risk does not necessarily have to involve the transfer of power from risk managers, i.e. it need not be zero-sum (Chambers 2006b).

Drawing on the findings presented here and the wider literature about participatory risk reduction and citizen science, several observations can be made about the opportunities in the different cases analysed in the thesis, that if taken, could facilitate greater risk reduction in these localities or elsewhere. In a context where there are both high levels of risk and a devolution of risk management responsibility to citizens, there are more likely to be collaborative participatory monitoring initiatives contributing to DRR and DRM. If there is a high level of risk, but more technocratic forms of risk management, then participatory monitoring (if it occurs) is likely to be scientist owned or led. In localities where there is a low level of risk and technocratic risk management, there is less likely to be any participatory monitoring. Finally, with lower levels of risk and citizens with more risk management responsibility, participation is less likely to be between citizens and VMIs unless they are particularly intentional about it. In this domain participatory monitoring is more likely to be between citizens and researchers or NGOs, or citizens on their own.

## 6.4 Transformation of power dynamics?

A constant theme throughout the thesis, is the potential for participation to either signal or facilitate a transformation of power dynamics within and between communities, organisations, and institutions. As suggested in Chapter 2, a transfer or sharing of power is recognised as a useful agent for success irrespective of the knowledge tradition from which the initiative arises. Evidence presented in Chapters 5 and 4 shows that citizens and communities in Ecuador were empowered in the face of risk through community-based monitoring to develop CBDRR.

Reconsidering the three principles of participation outlined in the analysis by Le De et. al. (2014), and re-examining the conceptual framework outlined in Mark Pelling's work (Pelling 2007), the evidence presented in the thesis supports the theory suggested in Chapter 2. Namely, that participation can reduce risk, even if it does not directly benefit participants, and it can exist (albeit with some difficulty) in contexts that are extremely technocratic. Thus whilst power is a useful analytical lens, participatory monitoring may often, by its very nature, be extractive or of little direct benefit to the participants. The comparison in Chapter 5 of the Ecuadorean with the Montserratian case studies suggests that under relatively less technocratic risk governance regimes is participatory monitoring more likely to lead directly to sustained community empowerment. In the case of Montserrat the initial involvement of citizens had little impact on decisions or policies regarding how risk was managed once they had undergone transformational changes.

In Ecuador the community were the owners of the knowledge produced, empowering them to make decisions at a community level (Chapter 4), whereas in Montserrat it was the volcano observatory that owned the knowledge that participatory monitoring produced, where that knowledge was then used to inform risk management decisions (Chapter 5).

Despite challenges with achieving local ownership (and indeed questions over its appropriateness in all contexts), policy change, or empowerment in a normative or even zero-sum sense (Chambers 2006b), participatory monitoring nonetheless can have substantive impact on risk reduction, in addition to providing data to monitoring scientists, through the further development of some forms of agency for those at risk.

## 6.5 The roles of participatory monitoring

It is evident that participatory monitoring has two broad roles for risk reduction and management: i) short-timescale risk reduction and response roles ii) longer term capacity building and learning roles. These will be discussed below.

### 6.5.1 Short timescale risk reduction and response

The examples in the thesis show the potential of participatory monitoring to stimulate or facilitate citizens, scientists and authorities to take risk-reducing adaptations in the face of the onset or escalation of a crisis. The literature in Chapter 2 and subsequent analyses demonstrate that there are four predominant ways in which these adaptations are made.

#### 6.5.1.1 Early warning systems

Participatory monitoring may directly feed into early warning systems across various contexts. The data themselves are used to inform, in real time, the evolution of hazardous phenomena. Furthermore, a network for monitoring that sends data to scientists or authorities may be used to communicate warning information in the other direction. The ways in which citizens participate in early warning systems may vary according to systems of risk governance and other contextual influences as described in Chapter 5, but broadly involves either participation in the production of knowledge that is fed into formal or technocratic systems of risk governance, with associated top-down risk management decisions, and the participatory monitoring that may be part of a community-based early warning system to support local decision-making and protective action.

#### 6.5.1.2 Fostering relational trust

The development of relational trust between stakeholders in a risk reduction process has been shown to be a key outcome of participatory monitoring. The thesis shows that repeated interactions over time, successful outcomes, shared experiences, values and other factors related to trust, such as those described in Chapter 4 or Haynes et al. (2008), are developed through participatory monitoring. Whilst most VMI cases from this thesis are expectant of relational trust benefits arising from participatory monitoring, some initiatives are more likely than others to achieve this central goal. This relational trust is of critical importance for timely responses to changes in risk over short timescales, such as evacuations, and over longer timescales for making risk reducing adaptations.

#### 6.5.1.3 Citizen learning and risk behaviour change

Participation in the production of knowledge, interactions with scientists and engagement with science as a process, create spaces for citizens to learn about the risks that they face. This learning can prompt behaviour change over both short and long timescales. Whilst increased hazard awareness as a result of participatory monitoring was not explored in depth analytically in this thesis, it was nonetheless stated by several VMIs in Chapter 3 as a rationale for them conducting participatory monitoring initiatives, and also described as a benefit by interview respondents in Chapters 4 and 5.

#### 6.5.1.4 Enhancing Agency

The above factors contribute towards an enhanced agency that all stakeholders may have to take risk reducing actions over short timescales. Citizen science more generally is known to enhance agency (Conrad and Hilchey 2011; Haklay 2012), and the development of agency or empowerment are explicit goals of PDRA processes and wider participatory DRR. This thesis also demonstrates that this agency isn't just individual for those participating citizens, but can also be collective agency for communities at risk.

### 6.5.2 Longer term capacity building and learning

Many disaster risk reduction and management processes occur over longer timescales outside of phases of acute crisis. These are typically related to the identification, management and mitigation of risks. Furthermore, research may add new insight in to the behaviour of hazards or the nature of vulnerability or exposure. Participatory monitoring may feed into these processes in a number of ways, as demonstrated in the thesis and discussed below.

#### 6.5.2.1 The production of research insight

An area that is not exploited to its fullest potential in either of the two case-studies from Chapter 5, along with many of the examples from Chapter 3 and the wider DRR literature, is the use of citizen derived data to generate new research insight, as is common in citizen science initiatives. Evidence presented here from both Chapter 3 and the case studies from Montserrat and Ecuador, suggests that for citizen derived data to be used for research purposes, this process needs to be driven by a key individual and collected in such a way as to be viable evidence supporting a research question or hypothesis. This ‘key individual’ effect could be considered as a hidden or sub part of the aggregated ‘Degree of Institutionalisation’ component in Figure 8. Long term success requires commitment, resource, and enthusiasm from both a research minded scientist and citizens, along with the occurrence of something to monitor, as suggested by various authors (e.g. Conrad and Hilchey 2011). Despite a knowledge of these necessary enabling factors, evidence elsewhere extolling the virtues and enormous potential of citizen science, this remains a largely untapped resource around volcanoes, with some notable exceptions in some localities (Loughlin et al. 2002a; Bernard 2013; Froude 2015).

#### 6.5.2.2 Longer term learning through participation: knowledge and change

Learning can be viewed from four perspectives: i) the production of new research insight (as discussed above) ii) the collective enhanced awareness of citizens around the volcano as a result of some of them participating in monitoring, iii) the ways in which the monitoring or risk management institutions have learnt to manage risk and iv) learning about participatory DRR processes.

Evidence from both volcanoes in Chapter 5's in-depth case studies suggest that the wider communities have learnt more about volcanic risk, partly as a result of of the participatory monitoring, and that it has enhanced relational trust by citizens learning that observatories are open and honest, or that scientists share similar values to themselves.

In Chapter 5, it was seen that the two both VMIs differed in terms of how they adapted participatory monitoring over time but there are considerable advantages to all VMIs that encourage and stimulate deeper reflection and learning. Evidence from the academic literature shows that institutions that are reflective about their practice, and reflexive about how they learn, are the most adaptable (Pelling et al. 2008; Matyas and Pelling 2015). Learning in this way about participatory monitoring has allowed the VMI responsible for monitoring Tungurahua, IGEPN, to help sustain the *vigías* network.

The fourth perspective suggests that learning about participatory DRR should, in its fullest sense, be participatory and, in an ideal world, be lead and initiated by the participants themselves, rather than by outside researchers (Pelling 2007; Le De et al. 2014). However, stimulating this self-reflection is challenging, as is retaining objectivity during self-evaluation, and future work on this topic could examine or attempt to catalyse evaluations of this kind.

#### 6.5.2.3 Participatory monitoring as a vehicle for other involvement in risk reduction processes

As suggested in previous chapters, participatory monitoring in many cases is about far more than the data alone. Benefits can extend beyond the knowledge that is produced, with the monitoring acting as a vehicle for further forms of engagement (Pelling 2007; Aitsi-Selmi et al. 2015; Stone et al. 2015). Similarly, other forms of participation can lead to citizens being involved in monitoring. The transitions between different participatory risk reduction activities are nuanced, but as suggested in Chapter 2, work by Haklay (2013) and others shows that citizens participating in the same initiative often have different levels of involvement at different times. Some are more or less involved in other forms of participation; some are more or less empowered to do so.

Citizens are also agents, and have varying degrees of agency for taking actions to reduce disaster risk. Of course, participating in monitoring or communication requires, or is, a manifestation of agency, but the thesis shows that it may enhance agency, thus lead to involvement in other risk management activities. Citizens may form local CBDRR committees (as in Chapter 4 or others (Maskrey 1989; Kelman et al. 2011; Ranmuthugala et al. 2013)), or less formally be actively involved in enacting risk management strategies to reduce vulnerability or mitigate risk (Pearce 2003). Citizens may also participate in risk management activities which are not owned by them or spatially situated within their community, i.e. by volunteering with civil defence agencies or in relief efforts (e.g. UNV 2012). In the absence of any formal scientific input, they can autonomously use local knowledge and experiences about hazards to reduce risk (Mercer et al. 2012a).

In Ecuador, it was clear that involvement initially in the early warning network, where *vigías* made observations about threatening activity meant that they simultaneously fulfilled many different roles. In Montserrat, participation was often in the form of helping in the field or with observational duties. However, scientists suggested in interviews that volunteers liked to have information that they could then tell their social networks, such that their roles were not restricted to knowledge production alone, but the volunteers fulfilled informal communication roles too.

The *vigías*, through participatory monitoring, then facilitated communities in making their own risk management decisions, with *vigías* involved in risk reducing measures such as evacuation plans, coordinating evacuations, the upkeep of infrastructure, and securing vulnerable elements of the community's infrastructure such as water storage.

In Montserrat, the story is rather different: the participation led to citizens acting as knowledge producers and communicators, but did not lead to participatory risk reduction in terms of action, and in many cases the form of risk governance closed off those spaces, where the reduction in participatory monitoring meant that any opportunity for further involvement on a path from here was unlikely. The nuance, however, of the Montserrat crisis is that some participants became staff at the volcano observatory, and one of the initial police-seconded volunteers from the beginning of the crisis is currently the director of Montserrat's disaster management agency. Similarly, several school students involved in the 'MVO Volunteer Scientist Programme 2012' (SAC 2012) (which the author helped to run) subsequently became paid interns at MVO (SAC 2013), and recently the Government of Montserrat provided funding for one of them to study a geology degree in the UK. The Volunteer Scientist Programme was not continued in subsequent years, with the director preferring to hire interns instead. Although citizens are not participating in a voluntary sense, in Montserrat they have made a transition to doing community-based monitoring and risk reduction within structures and institutions that have evolved during the crisis. Whilst it could be argued that this 'employment' may in some ways reduce the benefits of relative impartiality that ‘volunteers’ or those outside of an institution have, these now skilled and local scientists, technicians, and managers from the community are undoubtedly a considerable asset adding to the sustainability of monitoring there. It is also perhaps unsurprising that in a small country, citizens interested in voluntary risk management roles are likely to want to seek employment in that area and that this may be attainable for them.

Both of the examples in Chapter 5 demonstrate how participatory monitoring can be about more than knowledge production, and can act as a vehicle through which pathways to further collaboration or more established forms of CBDRR or CBDRM could be travelled down, as is the case elsewhere (e.g. Lawrence et al. 2006; Karnawati et al. 2011; Conrad and Hilchey 2011). The *vigías* demonstrated the enormous potential for empowering communities to make risk reducing adaptations that increase their resilience through the connections, relational trust, knowledge, and understanding that comes through persistent and active collaboration between citizens, scientists, and authorities (Twigg 2009; Stone et al. 2015). Volunteers in Montserrat demonstrated that although monitoring of a volcano can initially be outsider driven, either from other countries or regions, this can develop over time into a community-based institution where many of the volunteers become employed as staff. It could be argued that considering the form of risk governance in Montserrat, that this was the best possible outcome of participation where perhaps more inclusive forms of risk management and decision-making that are seen in Ecuador are not viable.

Using the conceptual framework synthesised in Chapter 2, potential transitions in the roles of citizens can be explored and described. A citizen participating in a citizen science activity that is designed to generate data for research about a physical hazard is likely to learn through the process (as demonstrated in Chapters 4 & 5). This learning is likely to result in the citizen sharing that learning with people in their social or family network, thus their role may transition from knowledge producer into producer and communicator.

Similarly, a citizen may facilitate the monitoring of flooding from a local river, knowledge that they then use to plan possible flood mitigation for their community. Thus this citizen may transition from a knowledge producer to an individual with agency to take or stimulate risk reducing adaptations.

Understanding drawn from the thesis can extend across to other localities, scales, and strengthen work in other hazard contexts (e.g. landslides), as described in Chapter 2. Citizens may also play active roles in communicating knowledge that has been produced by themselves or by others through participatory monitoring and other participatory processes. Some of this communication comes in the form of risk education or the enhanced learning of those in their social networks (Pelling et al. 2008; Bonney et al. 2009; Rouwet et al. 2013). Citizens can have communication roles in early warning networks (Karnawati et al. 2011; Cadag and Gaillard 2012) & (Chapter 4). Citizens also may communicate knowledge in the form of advocacy vertically to authorities that share responsibility for DRR (Maskrey 2011; Conrad and Hilchey 2011; Holcombe et al. 2011).

All of the above processes can change or be changed by the systems of risk governance within which they operate. Furthermore, knowledge and change may be co-produced by citizens, scientists and authorities engaged in participatory monitoring. The thesis demonstrates that there is no one model of best practice and no single role for citizens, but that adaptable institutions and organisations can evolve participatory monitoring organically to fulfil a number of roles that may best achieve risk reducing outcomes, depending on the contexts that initiatives are operating in.

## 6.6 Further work

A global perspective followed by in depth analyses of successful participatory risk reduction initiatives can yield both important research and practical insights. This thesis has explored the roles of participatory monitoring in reducing risk around volcanoes. It has raised a number of avenues for further research:

I. The thesis has developed conceptual understanding of the ways in which different participatory monitoring approaches may lead to risk reduction. Further work should explore the development of an evaluative framework (e.g. Appendix F) based on the model described in (Figure 8).

II. The thesis has primarily explored participation between citizens and scientists working at volcano monitoring institutions, thus within and outside of volcanic contexts there is value in further research examining processes where citizens participate with other actors, such as research scientists or NGOs.

III. The importance of 'key individuals' has arisen from various sections of this thesis, and further research on this concept would yield valuable insight not only to the development of participatory monitoring, but also theories of institutional change and practice in risk management institutions.

IV. Citizen science has limited adoption, either in practice or in the published research literature on DRR, however this thesis and the wider literature suggests that there is considerable potential for it. Further work should seek to explore ways of building research worthy data-sets from citizen derived data in volcanic areas and other DRR contexts.

V. With the demonstrable importance of citizens participating with scientists in monitoring for early warning, further work should be done to see if participatory early warning or DRR done without collaboration with scientists (as is often the case for NGOs) is as effective as it could be. Work could investigate how it might be strengthened through engagement with scientists, where there will be inevitable issues with scalability.

VI. Understanding why some participatory DRR initiatives are de-coupled from local monitoring institutions in volcanic areas, such as those described by Bowman and White (2012) or the ‘Merapi Ring’ in Indonesia (ComDevAsia 2011), would yield valuable insight for future initiatives.

VII. The potential for participatory monitoring, of any hazard, in stimulating capacities that develop community resilience, across various contexts, is an avenue of future research with numerous potential applications to both research and practice, particularly for NGOs. There is considerable potential for this in landslide or flood risk reduction, and for adaptations to longer term stresses such as climate change in the developing world.

# List of Acronyms

| | |
|---|---|
| BGS | British Geological Survey |
| CBDRM | Community-Based Disaster Risk Management |
| CBDRR | Community-Based Disaster Risk Reduction |
| CBEWS | Community-Based Early Warning System |
| CBM | Community-Based Monitoring |
| DRM | Disaster Risk Management |
| DRR | Disaster Risk Reduction |
| ESRC | Economic and Social Research Council |
| EWS | Early Warning System |
| GAR15 | Global Assessment Report 2015 |
| GNS | Geological and Nuclear Sciences |
| IGEPN | Instituto Geofísico, Escuala Politécnica Nacional |
| IPGP | *Institute du Physique du Globe de Paris* |
| MVO | Montserrat Volcano Observatory |
| NGO | Non-Governmental Organisation |
| PDC | Pyroclastic Density Current |
| PDRA | Participatory Disaster Risk Assessment |
| PGIS | Participatory Geographical Information System |
| PRA | Participatory Rural Appraisal |
| RRA | Rapid Rural Appraisal |
| SAC | Scientific Advisory Committee |
| SFDRR | Sendai Framework for Disaster Risk Reduction |
| SHV | Soufrière Hills Volcano |
| SRC | Seismic Research Center |
| SRU | Seismic Research Unit |
| STREVA | Strengthening Resilience in Volcanic Areas |
| UNISDR | United Nations International Strategy for Disaster Reduction |
| USGS | United States Geological Survey |

| | |
|---|---|
| VAACs | Volcanic Ash Advisory Centres |
| VDAP | Volcano Disaster Assistance Program |
| VMI | Volcano Monitoring Institute |
| WOVO | World Association of Volcano Observatories |

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# Appendix A *Vigías* journal article

Journal of Applied Volcanology
a SpringerOpen Journal

RESEARCH Open Access

# 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 (Auker 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 11$^{th}$ 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 16$^{th}$ October (Tobin & Whiteford 2002). Activity increased to include violent Strombolian and small Vulcanian explosions from the 28$^{th}$ October, with the first eruptive phase lasting until 10$^{th}$ 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, Escuala 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

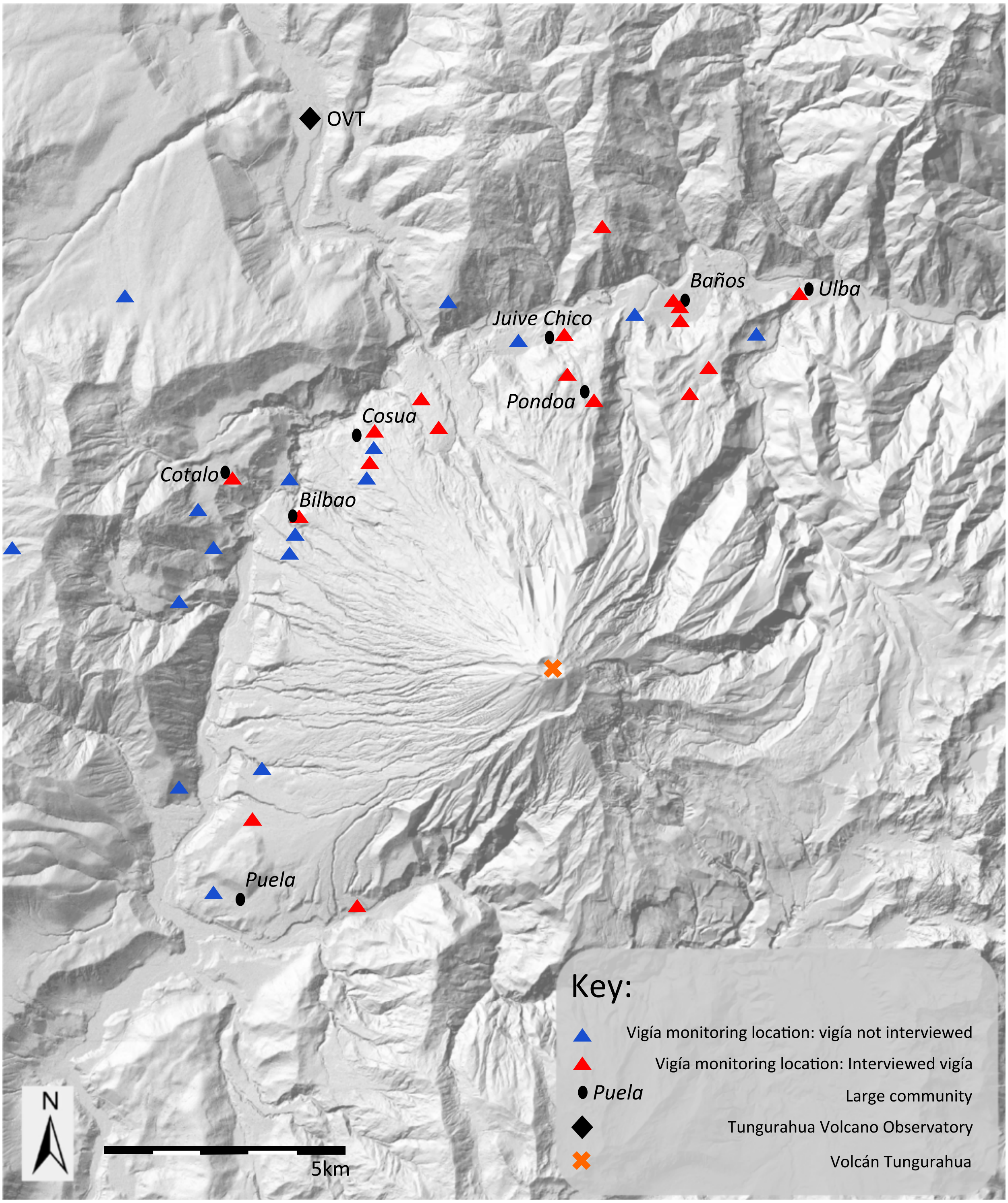


**Figure 1 Map of the vigías locations.** Map showing the locations of *vigías* relative to the volcano, population centres and the volcano observatory.

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 *vigía*** | |
| 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 *vigía* | 1 |
| National Secretariat for Risk Management (SNGR) | 2 |
| Scientists | 4 |

*Los Ojos del Volcán,* which disbanded soon after the reoccupation 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

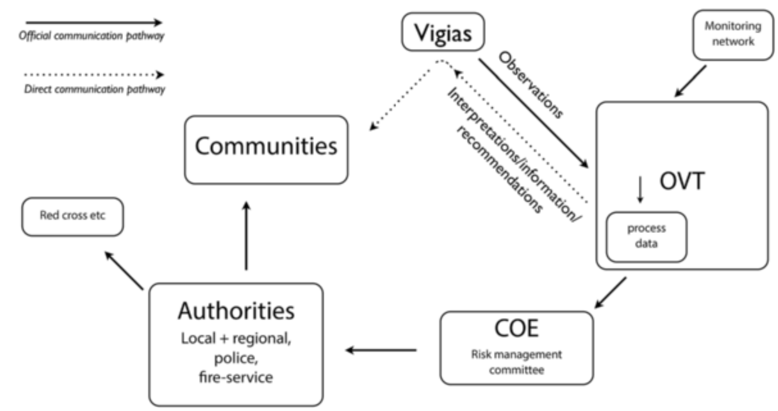


**Figure 2 Communication network.** Diagram showing the volcanic risk communication network, with its official pathway and direct (*vigía* mediated) pathway.

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

[a]The 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.

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# Appendix B Global VMI survey

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## Public participation in volcanology

Summary | Design Survey | Collect Responses | Analyze Results



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*Public participation in volcanology*

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**Upgrade to Add More Questions**

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This survey is about members of the public being involved in monitoring, observing, analysis of data, outreach and communication, or participation in research on volcanoes and volcanic processes. We would like to know if you involve members of the public in any way, and hope that you can tell us why you do (or don't). Your responses will help us and the wider volcanology community to know more about public participation in volcanology around the world.

This work is part of a PhD project at the School of Environmental Sciences, University of East Anglia. The research is funded by the Economic and Social Research Council (ESRC) and the British Geological Survey (BGS), UK.

Please contact us if you have any questions:
jonathan.stone@uea.ac.uk

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Upgrade to Add More Questions

Q1 Edit Question ▼ Move Delete

**✱1. In which country is your institution?**

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Q2 Edit Question ▼ Move Delete

**✱2. What is the name of your institution?**

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Q3 Edit Question ▼ Add Question Logic Move Delete

**✱3. What type of institution are you?**

- Volcano observatory that monitors a single volcano
- Volcano observatory that monitors more than one volcano
- Regional monitoring organisation
- Mainly research funded organisation (University or Research Institute)
- Large research institution including a volcano monitoring department.
- Geological Survey
- Other (please specify)

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Q4 Edit Question ▼ Move Delete

**✱4. How many volcanoes does your institution monitor?**

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Q5 Edit Question ▼ Move Delete

***5. Where does your funding come from?**

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Q6 Edit Question ▼ Move Delete

***6. In what year was your institution established (under its current or previous name(s)) ?**

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Q7 Edit Question ▼ Move Delete

***7. How do you or would you communicate or interact with the public in the following cases?**

| | Education and Engagement | During a crisis |
|---|---|---|
| Social Media | | |
| Interactions during planning meetings | | |
| TV | | |
| Face to face interactions in communities | | |
| Informal discussions | | |
| Educational Leaflets | | |
| Work in schools | | |
| Radio | | |
| Public meetings | | |
| Hazard Maps | | |
| Public lectures | | |
| Through people in the community | | |
| Websites | | |
| Workshops | | |

Surveys

Other (please specify)

Upgrade to Add More Questions | Split Page Here

Q8 Edit Question ▼ Move Delete

***8. Please indicate in which case you think the following are most effective for communication and interaction with the public.**

| | Education and Engagement | During a crisis | Of equal importance |
|---|---|---|---|
| Social Media | | | |
| Interactions during planning meetings | | | |
| TV | | | |
| Face to face interactions in communities | | | |
| Informal discussions | | | |
| Educational Leaflets | | | |
| Work in schools | | | |
| Radio | | | |
| Public meetings | | | |
| Hazard Maps | | | |
| Public lectures | | | |
| Through people in the community | | | |
| Websites | | | |
| Workshops | | | |
| Surveys | | | |

Other (please specify)

Upgrade to Add More Questions | Split Page Here

Q9 Edit Question ▼ Edit Question Logic (2) Move Delete

***9. Does your institution have a member of staff responsible for Outreach and Education?**

Yes

No

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Upgrade to Add More Questions

**Q10** Edit Question ▼ Move Delete

**∗ 10. For how long have you had a member of staff responsible for outreach and education or public engagement?**

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**Q11** Edit Question ▼ Edit Question Logic (2) Move Delete

**∗ 11. Have members of the public ever been involved in the collection or analysis of any data or observations related to volcanic activity?**

Yes

No

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How the public participate

Upgrade to Add More Questions

**Q12** Edit Question ▼ Move Delete

**∗ 12. When were members of the public first involved? (Please state the year)**

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**Q13** Edit Question ▼ Move Delete

**∗ 13. What first prompted the involvement of members of the public?**

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Q14 Edit Question ▼ Add Question Logic Move Delete

*** 14. When have they/are they involved?**

All of the time

During periods of activity

For specific projects

At certain times of the year

Occasionally

Other (please specify)

Upgrade to Add More Questions | Split Page Here

Q15 Edit Question ▼ Add Question Logic Move Delete

*** 15. What type of monitoring or observations have they been involved with? (Select all that apply)**

Observations (written/oral recording or reporting)

Photography - occasional / in response to events

Photography - repeated / systematic

Video recordings

Tephra fall collection

Retrospective eyewitness accounts of events

Other (please specify)

Observatory duties

Field assistants

Verify observatory or remote observations in-situ

Mapping

Volunteering as local guides for scientists?

Upgrade to Add More Questions | Split Page Here

Q16 Edit Question ▼ Add Question Logic Move Delete

*** 16. Who manages their involvement? (select all that apply)**

The chief scientist (from my organisation)

A scientist (from my organisation)

The outreach/communication person (from my organisation)

A researcher from another organisation

A member of the local community

Other (please specify)

Upgrade to Add More Questions Split Page Here

Q17 Edit Question ▼ Add Question Logic Move Delete

**∗ 17. How is their involvement managed? (select all that apply)**

Via face to face communication

Via radio

Via telephone

By email

By a website

By social media

Through a school/college

Other (please specify)

Upgrade to Add More Questions Split Page Here

Q18 Edit Question ▼ Add Question Logic Move Delete

**∗ 18. Who uses the information that they collect? (select all that apply)**

The observatory for its general monitoring

Scientists within the observatory for a particular study

Researchers from another organisation

Hazard/risk managers

The data are stored / archived but currently are not used / analysed

The data are not used or retained for future use

Other (please specify)

Upgrade to Add More Questions Split Page Here

Q19 Edit Question ▼ Edit Question Logic (2) Move Delete

**∗ 19. Are participants ever involved in analysing any of the data collected?**

Yes

No

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Upgrade to Add More Questions

Q20 Edit Question ▼ Move Delete

**∗20. Please describe briefly the analysis methods used**

Upgrade to Add More Questions Split Page Here

Q21 Edit Question ▼ Move Delete

**∗21. How did you develop or identify the methods to use for involving the public?**

Upgrade to Add More Questions Split Page Here

Q22 Edit Question ▼ Move Delete

**22. If you used to involve members of the public, but no longer do so - can you tell us why?**

Upgrade to Add More Questions

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About the participants

Upgrade to Add More Questions

Q23 Edit Question ▼ Move Delete

**∗23. Approximately how many people are/have been involved?**

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Q24 Edit Question ▼ Move Delete

**∗24. Please give us any information that you can about profile of the people who take part, such as their age distribution, their gender, or their social or occupational background?**

Upgrade to Add More Questions Split Page Here

Q25 Edit Question ▼ Add Question Logic Move Delete

**∗25. Have any of the participants gone on to be employed at some point by your organisation in a volcanology, monitoring, technical, communication or risk management role?**

Yes

No

If yes, please specify what role

Upgrade to Add More Questions Split Page Here

Q26 Edit Question ▼ Add Question Logic Move Delete

**∗26. Have any of the participants gone on to work in a volcanology, monitoring, technical, communication or risk management role in another organisation?**

Yes

No

If yes, please specify what role

Upgrade to Add More Questions

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Why does your organisation involved the public?

Upgrade to Add More Questions

Q27 Edit Question ▼ Move Delete

**✱27. Please state how much you agree or disagree with the statements below**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| During an eruption members of the public gather valuable data that we would otherwise be unable to collect. | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| The observatory has limited resources, so it would be difficult to comprehensively monitor without members of the public helping. | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| The public collect forms of data that are not prioritised by the scientists but which are useful for **monitoring**. | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| The public collect forms of data that are not prioritised by the scientists but which are useful for **research**. | | | | | | |

Any comments?

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Upgrade to Add More Questions

Q28 Edit Question ▼ Move Delete

**✱28. Please state how much you agree or disagree with the statements below**

| Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|

We involve the public because they want to be involved.

Any comments?

We involve the public as a way of educating them about the volcano and its hazards.

Any comments?

We involve the public in an effort to increase their trust in the advice given by our organisation?.

Any comments?

Upgrade to Add More Questions

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The outcomes of involving the public

Upgrade to Add More Questions

Q29 Edit Question ▼ Add Question Logic Move Delete

***29. What is the general quality of the data collected by the participants?**

| Very poor quality | Poor quality | Reasonable quality | Good quality | Very good quality |
|---|---|---|---|---|

Any comments?

Upgrade to Add More Questions Split Page Here

Q30 Edit Question ▼ Move Delete

***30. Please state whether you agree or disagree with the statements below**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Involving the public improves our relationship with them | | | | | | |

Any comments?

Improving our relationship with the public increases the effectiveness of our risk communication

Any comments?

Involving the public improves their uptake of hazard knowledge/awareness

Any comments?

Involving the public is important for the collection/generation of data for research on volcanic phenomena

Any comments?

Involving the public means that we can better understand what happens during an eruptive event

Any comments?

Involving the public increases their trust in us

Any comments?

Upgrade to Add More Questions

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What concerns do you have about involving the public?

Upgrade to Add More Questions

**Q31** Edit Question ▼ Move Delete

**✱31. Please state whether you agree or disagree with the statements below**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Our scientists and monitoring network provide all of the data/observations that we need | | | | | | |

Any comments?

Data/observations collected by members of the public is/would be too basic to be of scientific use

Any comments?

Data/observations collected by members of the public is/would be too poor in quality to be of use

Any comments?

Involving the public is a drain on resources

Any comments?

Close involvement with the public could affect scientists' objectivity when giving advice/making decisions

Any comments?

Involving the public could increase the spread of competing (or negative) messages about the volcano and its hazards

Any comments?

Members of the public do not want to be involved

Any comments?

Upgrade to Add More Questions Split Page Here

Q32 Edit Question ▼ Move Delete

**32. Do you have any other concerns?**

Upgrade to Add More Questions

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Why doesn't your organisation involve the public?

Upgrade to Add More Questions

Q33 Edit Question ▼ Move Delete

*** 33. Please state whether you agree or disagree with the statements below**

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Our scientists and monitoring network provide all of the data/observations that we need | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Data/observations collected by members of the public is/would be too basic to be of use | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Data/observations collected by members of the public is/would be too poor in quality to be of use | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Involving the public is a drain on resources/time | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Close involvement with the public could affect scientists' objectivity when giving advice/making decisions | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Involving the public could increase the spread of competing (or negative) messages about the volcano and its hazards | | | | | | |

Any comments?

| | Strongly disagree | Disagree | Neither | Agree | Strongly agree | Not sure |
|---|---|---|---|---|---|---|
| Not enough people want to be involved | | | | | | |

Any comments?

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Q34 Edit Question ▼ Move Delete

**34. Do you have any other concerns?**

Upgrade to Add More Questions

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Future plans

Upgrade to Add More Questions

Q35 Edit Question ▼ Edit Question Logic (1) Move Delete

**✱35. Do you intend to involve members of the public in the future?**

Yes

No

Maybe

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Upgrade to Add More Questions

Q36 Edit Question ▼ Move Delete

**✱36. What will future participants do?**

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Additional comments

Upgrade to Add More Questions

Q37 Edit Question ▼ Move Delete

**37. Do you have any additional comments that will help us to understand your views or experience of public involvement?**

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Thank You!

Thank you for filling out this survey. We really appreciate and value your responses. If you have any questions, then please don't hesitate to contact us.

Upgrade to Add More Questions

Q38 Edit Question ▼ Move Delete

*** 38. Please provide us with your contact details**

**Name:**

**Email Address:**

Upgrade to Add More Questions Split Page Here

Q39 Edit Question ▼ Move Delete

**39. If you know of anyone else, or any other institution that involves the public in the collection/analysis of data or observations related to volcanic activity, please can you provide us with their contact details?**

Name

Institution

Email address

Upgrade to Add More Questions

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Back to My Surveys

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# Appendix C *Vigías* topic guide

### *Vigía* interview questions and topic guide

| Topic | Question | *Supplementary questions* |
|---|---|---|
| **About** | Tell us about yourself? | *(Include occupation/previous occupation, where they live, family etc)* |
| **Motivations/initiation** | What led you to become a *vigía*? | *Did they volunteer? Did a scientist approach them? Who didn't become one?* |
| **Motivations/initiation** | What are the benefits of being a *vigía* ? | *Do they get paid? Has that always been the case? How has it changed? Benefits to others?* |
| **Practices** | What do you do as a *vigía*? | *Ask about: observations, how often they make observations and how often they talk to the scientists, equipment maintenance, radio communication, ash recording?* |
| **Practices** | How has your role changed over time or changed with volcanic activity? | *Do they do it routinely every day, week, month? Or do they do it when there is heightened activity? Try and ask why roles may have changed* |
| **Communication** | Who do you communicate with? Who in your village/town? Which scientists? When? | *Do they transfer information from scientists to their village/family & friends? Or do they just communicate with scientists to give them information* |

| | | |
|---|---|---|
| **Knowledge transfer** | Do you think that the people in your family/village/town know more about the volcano and its dangers because you are a *vigía* ? | *If yes, then why? Because they tell them or because they more frequently listen to scientists etc? Are vigía s a conduit of awareness and knowledge?* |
| **Importance of role/impact** | What do your friends, family and other people in your village/town think about you being a *vigía* ? | *Is it an important job? Do they like you doing it? Do they have any concerns?* |
| **Effect of *vigías*, Examples** | Do you think that your village/town is safer because there is a *vigía* ? Can you give an example of this? | *This is about the effects of the vigías on risk reduction.* |
| **Relationships + trust** | Since you have been a *vigía*, how has your relationship with the scientists changed? | *Which scientists? How? When? Why?* |
| **Relationships + trust** | How do you feel about the scientists? Has this changed since you have become a *vigía*? | *Do your friends feel the same way?* |

# Appendix D UNISDR case study

# UNISDR Science and Technical Advisory Group Case Studies – 2014

## Integrating community and observatory based monitoring to reduce risk at volcán Tungurahua, Ecuador

### The problem

Long-lived episodic volcanic eruptions share the risk characteristics of other forms of extensive hazard (such as flood, drought or landslides). They also have the capacity for escalations to high intensity, high impact events. Volcán Tungurahua[1] in the Ecuadorian Andes has been in eruption since 1999 and represents one such challenge for forecasting and managing repetitive long-term risk. The forcible re-occupation of evacuated areas early in the eruption[2] demonstrated communities' desire to remain close to the volcano despite the episodic risks, however there was limited trust in scientific advice, an important factor in risk communication[3]. In these circumstances effective early warning and well-rehearsed and efficient evacuation becomes critical.

### The science

Volcán Tungurahua is monitored by the Instituto Geofísico, Esceula Politecnia Nacional (IG-EPN) and managed by the local civil protection organisations. Resources were not sufficient to monitor and manage evacuations on all flanks occupied by communities. Thus, a network of volunteers (called '*vigias*'), formed from people already living in the communities at risk, was created with two main goals in mind: (i) to facilitate timely evacuations as part of the civil protection communication network, including the management of sirens, and (ii) to communicate observations about the volcano to the scientists[4].

Photo 1: Tungurahua with Baños in the foreground and communities on the flanks

The current network consists of around 25 *vigias* who use radios with which they maintain daily contact with the observatory. Some now assist with maintenance of the scientific monitoring equipment near their homes or land and make daily observations that add considerably to the sum of knowledge of the range and impact of the volcanic behaviour[5] often assisting with visual confirmation of inferred activity seen on the geophysical monitoring network. They facilitate community-level preparedness activities, such as evacuation drills and resource planning. This case draws on an analysis of these components[4] using mixed qualitative methods, drawing on earlier studies of social response to eruptions at Tungurahua[5].

### The application to policy and practice

So far, the communities have responded dynamically to the risk from the volcano, allowing them to live in close proximity and evacuating rapidly when necessary in consultation with the IG-EPN and local civil protection. Community trust in scientific advice and information has reformed since the difficult events of 1999, with vigias acting as intermediaries; and the vigias have received training from IG-EPN about what to observe, how to describe phenomena and how to communicate with the local observatory. Although initiated by Civil Defence with official civil defence volunteers, unlike a volcano observatory, the network is not incorporated as part of a statutory body. Nevertheless, in practice it fulfils an official role, with risk management authority uniforms, backing and resources.

### Did it make a difference?

This enables the community to continue their way of life alongside the volcano when it is relatively quiet and to prepare for and rapidly mobilize themselves during acute activity. The network of *vigias* has greatly assisted the monitoring efforts of scientists providing visual observations and by maintaining equipment[6]. Frequent interactions with the scientists have fostered strong trust-based relationships, allowing the *vigias* to act as intermediaries between scientists and the communities during risk communication[4].

*"The scientists are people who we can talk to and this shows a growth in trust. 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" - vigia* of volcán Tungurahua.

Photo 2: *Vigias* and a scientist, with an exemplary quote about their relationship

Prompt evacuations without loss of life during escalations of activity since 2000 can be attributed to the role of the 'vigias'. Following loss of life in 2006 the network was increased to include communities where mortalities occurred. Volcán Tungurahua is capable of larger-scale activity than has occurred since 1999 and so the network has not been tested for a large escalation in impact, but the trust developed by the network should engender the capacity for action should such an eruption be sufficiently forecasted. The network is a pragmatic response to a real risk problem and is driven by all stakeholders.

Apart from reducing volcanic risk, the network has been able to coordinate the response to fires, road traffic accidents, medical emergencies, thefts, assaults and to plan for future earthquakes and landslides

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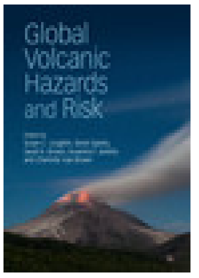
Authors: Jonathan Stone (University of East Anglia/British Geological Survey), Jenni Barclay (University of East Anglia), Patricio Ramon (IGEPN, Ecuador), Patricia Mothes (IGEPN, Ecuador), Sue Loughlin, British Geological Survey, STREVA Team (various)

# Appendix E Book chapter




Global Volcanic Hazards and Risk

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# Chapter 26

## Communities coping with uncertainty and reducing their risk: the collaborative monitoring and management of volcanic activity with the *vigías* of Tungurahua

J. Stone, J. Barclay, P. Ramon, P. Mothes and STREVA

Long-lived episodic volcanic eruptions share the risk characteristics of other forms of extensive hazard (such as flood, drought or landslides). They also have the capacity for escalations to high intensity, high impact events. Volcán Tungurahua in the Ecuadorian Andes has been in eruption since 1999. The management of risk in areas surrounding the volcano has been facilitated by a network of community-based monitoring volunteers that has grown to fulfil multiple risk reduction roles in collaboration with the scientists and authorities.

### 26.1 Inception and evolution

Renewed activity from Tungurahua (1999) prompted the evacuation, via Presidential Order, of the large tourist town of Baños and surrounding communities. Social unrest associated with the displacement and attendant loss of livelihood culminated in a forcible civil re-occupation of the land, crossing and over-running military checkpoints (Le Pennec et al., 2012). This re-occupation prompted a radical re-think of management strategy around the volcanic hazard, shifting emphasis from enforcement to communication (Mothes et al., 2015). This enabled the community to continue their way of life alongside the volcano when it is relatively quiet and to prepare for and rapidly mobilise themselves during acute activity.

To do this, a network of volunteers, formed from people already living in the communities at risk, was created with two main goals in mind: (i) to facilitate timely evacuations as part of the Civil Defence communication network, including the management of sirens, and (ii) to communicate observations about the volcano to the scientists (Stone et al., 2014). These volunteers are collectively referred to as '*vigías*' and their input provides a pragmatic solution to the need for better monitoring observations and improved early warning systems when communities are living in relative proximity to the hazard. As a part of the solution, the communities feel strong ownership and involvement with the network (Stone et al., 2014). The communication pathways, formal and informal are shown in Figure 26.1.

Stone, J., Barclay, J., Ramon, P., Mothes, P. & STREVA (2015) Communities coping with uncertainty and reducing their risk: the collaborative monitoring and management of volcanic activity with the vigías of Tungurahua. In: S.C. Loughlin, R.S.J. Sparks, S.K. Brown, S.F. Jenkins & C. Vye-Brown (eds) *Global Volcanic Hazards and Risk,* Cambridge: Cambridge University Press.

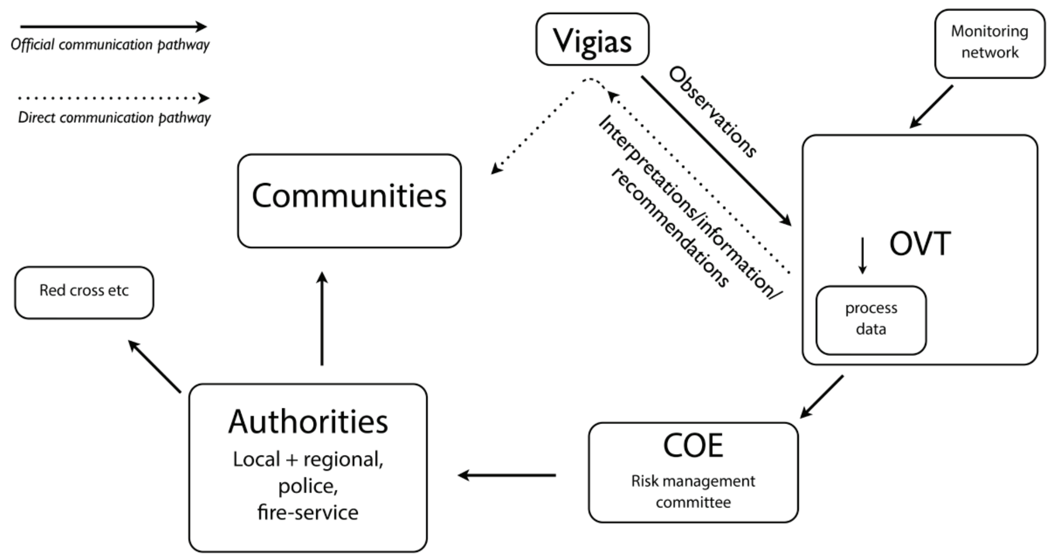


*Figure 26.1 The volcanic risk communication network, with its official pathway and the more direct 'vigía mediated' pathway. Adapted from Stone et al. (2014).*

## 26.2 Success and value of the network

The current network consists around 25 *vigías* who use radios with which they maintain daily contact with the observatory (see Figure 26.2). In theory there are up to 43 *vigías,* but not all have radios or actively take part currently. The network has been sustained and has even grown since its inception in 2000. There was a rapid expansion in numbers of *vigías* after the August 2006 eruption. This was a pivotal event, whereby lives saved in the Juive Grande area were attributed to the presence of *vigías* working with the local volcano observatory and lives lost in Palitahua were thought to be in part due to a lack of *vigías* there (Stone et al., 2014). No loss of life has been recorded in recent events in July and October, 2013 and on 1 February 2014 and this can be attributed to the prompt actions to evacuate and reduce risk via the network. Further, community trust in scientific advice and information has reformed since the events of 1999, with vigías acting as intermediaries. Some of the *vigías* now maintain the scientific monitoring equipment near their houses and make daily observations that add considerably to the sum of knowledge of the range and impact of the volcanic behaviour (Bernard, 2013, Mothes et al., 2015), often assisting with visual confirmation of inferred activity seen on the geophysical monitoring network. Apart from reducing volcanic risk, the network has been able to coordinate the response to fires, road traffic accidents, medical emergencies, thefts, assaults and to plan for future earthquakes and landslides. The economic value of allowing affected communities to remain and adapt their existing livelihoods has not, as yet, been determined, but is considered by those communities to be immeasurable.

So far, the communities have responded dynamically to the risk from the volcano, allowing them to live in close proximity and evacuating rapidly when necessary. Tungurahua is capable of producing far larger eruptions than those seen in the last 14 years (Hall et al., 1999), but the trust developed by the network should engender the capacity for action should such an eruption be forecasted, and crucially allows the people to manage their risk in the mean-time, when long-term relocation is simply not an option.

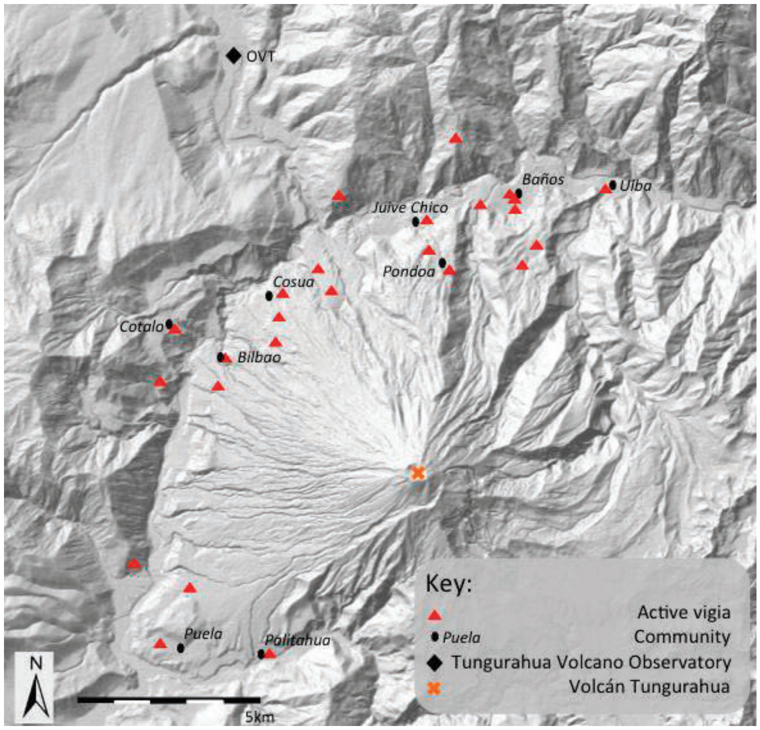


*Figure 26.2 Map showing the locations of vigías relative to the volcano and communities significantly affected by volcanic hazards (adapted from Stone et al. (2014)).*

## 26.3 Requirements of the network

Even now, the network still consists of volunteers; and the main requirement from all stakeholders is just the time needed to maintain shared goals and values. The voluntary aspect of the network is vitally important and the motivations of those involved are to help reduce risk to their communities. Nonetheless, its success is due to the willingness with which time is given by *vigías*, observatory scientists (and those in civil protection during its early years) to listen and to share. While some initial *vigías* were drawn from those already involved with Civil Defence (26%), many were also recruited by scientists due to their location relative to the volcano (21%), for their position in the community (26%) and ultimately through other *vigías* (5%). The *vigías* were given basic training from the scientists about what to observe, how to describe phenomena and how to communicate with the local observatory. The largest infrastructural investment was in a VHF radio network, upgraded by another volunteer, and the distribution of handheld radios. Radio communication is a key ingredient in developing relationships and is strictly and professionally observed: every night at 8pm, someone from civil protection calls on the joint (OVT, Civil Defence) radio system and asks the *vigías* to report in. If activity changes then communication frequency increases. Initially, if a *vigía* missed several radio checks they were told to participate properly or not be part of the team. Similarly a sense of shared pride in the role comes from the uniforms provided, initially, by civil defence.

## 26.4 Sustainability of the network

The network is entering into its fifteenth year; and like conventional geophysical monitoring instruments, relationships continue to function only with regular maintenance; in this instance through contact and discussion. Although the actual financial requirements are small; those that are required (maintenance of the radio network; uniforms) become important symbols to all for the value of the network; long-term neglect of this funding represents a significant threat.

The clear value that the transmission of timely messages to evacuate also reinforces the value of the *vigías and the scientists* to the wider community, providing a strong incentive to volunteers to continue. There is less evidence for whether these motivations would persist in the absence of a volcanic threat but this type of network is exceptionally well suited to extensive hazards and risks.

## 26.5 Risk reduction for more than 14 years

The sustained involvement of *vigías* (community-based monitoring volunteers) has allowed communities surrounding Tungurahua to live with dynamically changing risk. The network of *vigías* have greatly assisted the monitoring efforts of scientists providing visual observations and by maintaining equipment. Frequent interactions with the scientists have fostered strong trust-based relationships, allowing the *vigías* to act as intermediaries between scientists and the communities during risk communication. These activities have undoubtedly saved lives and helped to preserve livelihoods in the area. The nature of long-lived episodic volcanic eruptions, and thus their similarity to other extensive hazards, means that this type of approach could reduce risk in the case of flooding, landslides and droughts.

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# Appendix F Evaluation table for conceptual model

*To attain a certain level, an initiative must fulfil one of the indicators. The indicators are not exhaustive, but provide a qualitative description of the types of aspects of an initiative that matches a level.*

| | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| **Citizen Motivation** | Citizens rarely participate or rarely wish to | Citizens participate only when asked by VMI | Citizens volunteer observations regularly | Citizens are motivated to consistently volunteer time and effort to participatory monitoring | Citizens are highly motivated by the potential to reduce significant levels of risk to themselves and community. Or citizens are highly motivated to do detailed data collection and analysis. |
| **Risk governance responsibility** | Technocratic forms of risk governance, increases in risk managed by evacuations reducing exposure considerably | Some collaborative risk governance, but most participation is in the form of deliberation | Citizens have a voice and choice in risk management decisions, but there are sometimes mandatory evacuations. | Risk management responsibility is shared with citizens. Mandatory evacuations are rare or un-enforced. | Risk governance systems implictly or explicitly allow citizens to make choices about where they live/how exposed they are |
| **VMI institutionalising participatory monitoring** | Participation is ad hoc or sporadic | Participation is regular for some citizens, but VMI does not use the data. | There are some forms of participatory monitoring, but poorly resourced | There is an institutional programme or priority for participatory monitoring | Participatory monitoring is a key part of the institution's ways of working |
| **Risk context** | No recent eruptions or observable hazards | Some non-eruptive hazards and exposed communities | Infrequent periods of activity or periods of high risk | Frequent periods of high risk | There is consistently high levels of risk |
| **Relationships leading to trust** | Poor relationships between scientists and citizens. Conditions of mis-trust | Citizens and scientists building relationships. | Developing relationships, but trust is limited to participants (not wider community) | Good relationships between citizens and scientists, improved trust between community and scientists | Well developed trust based relationships between scientists and citizens over considerable lengths of time that facilitate risk reducing adaptations |
| **Adaptive capacity of initiative** | Participation is a one off | Some evidence of initiative making small adaptations. Evidence that some changes have exceeded adaptive capacity | Evidence of adaptations, such as widening participation, diversification of roles. Evidence that some changes have exceeded adaptive capacity | Both citizens and scientists and the initiative show the ability to adapt incrementally over time. Evidence of roles going beyond monitoring to other DRR | The initiaitve has often demonstrated the capacity to adapt to significant changes in context to continue to deliver risk reduction benefits |