

Experiences of challenge-led research in earthquake-prone and volcanic regions

S. Sargeant and A. Hicks, British Geological Survey, Edinburgh, UK,

P. Sammonds, University College London Institute for Risk and Disaster Reduction,

London, UK, V. Sword-Daniels, ITAD, Hove, UK

Abstract

The UK's Increasing Resilience to Natural Hazards (IRNH) Programme was established in 2010 to support science-led research aiming to increase social and economic resilience in earthquake-prone and volcanic regions. IRNH marked a new direction for geoscience research in the UK: challenge-led, involving both physical and social science research disciplines (funded by two different research councils), and working with an impact focus in low and middle-income countries. In this paper, we provide some reflections on what has been achieved and what has been learned during IRNH about challenge-led interdisciplinary and transdisciplinary research that aims to support disaster risk reduction (DRR) and contribute to resilience-building processes. We structure our reflections around three aspects: project and programme management, success and achievement, and legacy. We hope that the lessons learned by the IRNH Programme will be of value to others who are working to better understand and manage disaster risk and other efforts to apply scientific advances to societal problems using interdisciplinary and transdisciplinary approaches.

Introduction

The UK's Increasing Resilience to Natural Hazards (IRNH) Programme was established in 2010 to support science-led research projects to assist in increasing social and economic resilience in earthquake-prone and volcanic regions (NERC-ESRC, 2011). IRNH marked a new direction for geoscience research in the UK because it was jointly funded by the Natural Environment Research Council (NERC) and the Economic and Social Research Council (ESRC). The research was to be challenge-led, involve both physical and social science research disciplines, and with a focus on increasing resilience in low and middle-income countries. The programme ends in 2019. In this paper, we provide some reflections on what the programme has achieved and what has been learned through the process about how science and researchers can contribute to disaster risk reduction (DRR) and resilience by working in this way. Toomey et al. (2015) point to the need to critically reflect on interdisciplinary or transdisciplinary research that aims to have some kind of societal benefit and this paper is an attempt to contribute to that endeavour. The paper is not intended to be an evaluation of the IRNH Programme, or of the projects within it, but rather a way to share some of the lessons that have been learned with a wider audience.

Background to the IRNH Programme

When the IRNH Programme began in 2010, it formed part of the Research Councils UK (RCUK) Global Uncertainties Programme (GUP; for full details, see Sammonds, 2018). This was funded through the NERC Natural Hazards theme in partnership with ESRC (NERC-ESRC, 2011). In November 2011, there was an announcement of opportunity for “science-led research grants to assist in increasing social and economic resilience in earthquake prone and volcanic regions” (ibid.). Following the call for proposals, two multidisciplinary research consortia were funded: Earthquakes without Frontiers (EwF) and Strengthening Resilience in Volcanic Areas (STREVA). EwF ran from July 2012-July 2018 and had the aim of increasing resilience to earthquakes along the Alpine-Himalaya Belt, focussing on Nepal and Bihar, Kazakhstan and NE China. STREVA runs from July 2012 – March 2019 and aims to develop innovative ways to analyse and understand volcanic risk. It has focused on volcanic sites in the Lesser Antilles, Ecuador and Colombia. Both projects have relied on close collaboration with project partners (e.g. disaster management agencies, universities, scientific institutes and NGOs) in the countries where they were working.

The institutional landscape in which the programme sits has evolved during that time (e.g. the transition from the Hyogo to Sendai frameworks; NERC is no longer involved in the GUP, which now has a focus on conflict, crime and security research). However, the goal of the programme has remained the same: “the integration of natural and social science research across the programme to enhance the potential for impact on those affected by

natural hazards, in the short and long term” (ibid.). This was to be achieved by taking a co-productive approach involving physical and social scientists, policy makers, civil society and other stakeholders (ibid.). At the time, it was a very different kind of research project to the more traditional single disciplinary work that has usually been funded before by NERC.

The other elements of the IRNH programme were a Strategic Advisor (the co-author, Peter Sammonds) whose responsibilities included developing the announcements of opportunities for the programme, providing advice to the research councils and the consortia, and acting as a liaison between the projects and the funders. Two knowledge exchange fellows were also recruited to help integrate the programme and maximise its impact (see Figure 1).

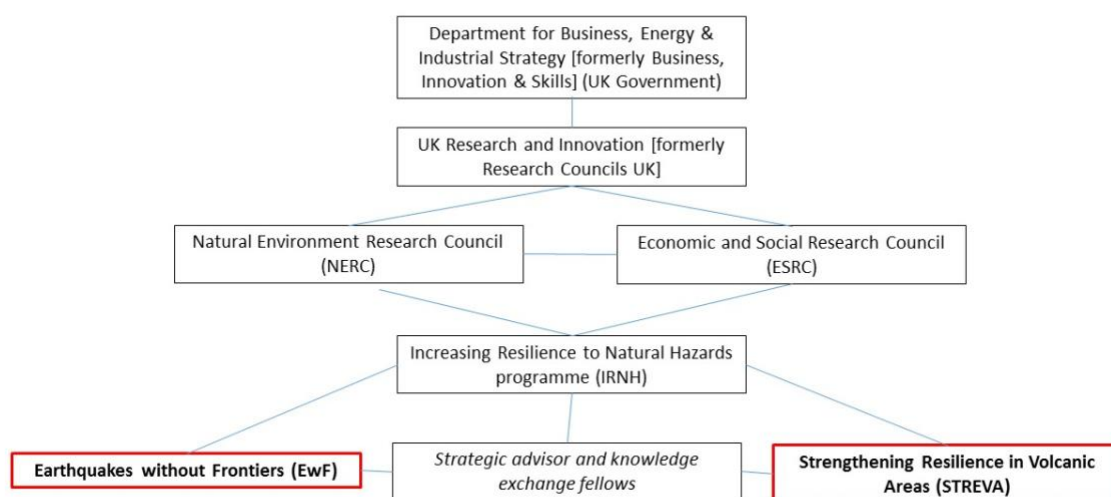


Figure 1: Organogram showing the relationships between different parts of the IRNH programme and its connection to other key funding institutions

Our approach

The goal of this paper is to reflect on what the IRNH programme has achieved and document some of the many lessons learned through the process about how scientific research can contribute to DRR and resilience-building. The findings are intended to complement the many other efforts to reflect on and learn lessons from doing interdisciplinary challenge-led research (e.g. Sillitoe, 2004; Marzano et al., 2006; Liu et al., 2008; Lyall et al., 2011; Lyall et al., 2013; Matso and Becker, 2014; DeLorme et al., 2016). These studies have tended to come from fields such

as agriculture, ecology, coastal science, water management and climate change research rather than earthquakes, volcanoes and their attendant hazards.

For our analysis, we have drawn on a range of information including academic and grey literature produced by the consortia, progress reports, reports from integrative workshops that brought the two projects together, and the report from a programme conference held at the Geological Society of London in 2017¹. We also use information about the projects e.g. the outputs, collaborations, follow-on funding that is held on researchfish[®]. The researchfish[®] online platform is used by UK Research and Innovation (UKRI, formerly RCUK) to measure research impact and designed to give a comprehensive view of how research leads to economic and social impact by capturing outcome, output and impact data. We have also conducted 19 key informant interviews with a subset of the researchers, five international partners and key programme staff. EwF and STREVA were roughly equally represented in the interviews. We aimed to ensure that this sample included senior and more junior researchers from both the physical and social sciences, but because we were not able to interview everyone, we recognise that it is unlikely that all points of view are represented here. We also draw on short interviews with several of the EwF researchers at the project's final meeting.

The interviews focussed on three aspects of the programme: (a) how the management and funding of IRNH influenced the projects, (b) what the projects have achieved, and (c) the potential legacy of the programme. These were recurring themes that emerged during discussions at various programme and project events. It should be noted that the authors of this paper are deeply embedded in the IRNH programme. Sargeant is one of the Knowledge Exchange (KE) fellows for the programme and was a co-investigator on EwF, focusing particularly on seismic hazard assessment and scientific capacity building in Kazakhstan. Hicks is also a KE fellow for the programme and was a post-doctoral researcher for STREVA from 2012-2017, focussing on social differentiation of vulnerability, risk communication and integration of research disciplines. Sammonds is the strategic advisor for the IRNH programme, and Sword-Daniels was a KE Fellow for the programme from 2013-2017. Sargeant and Hicks undertook the interviews but in order to maintain some 'distance', Sargeant interviewed researchers from STREVA and programme staff, and Hicks interviewed representatives from EwF.

¹ For more information see <https://www.geolsoc.org.uk/~media/shared/documents/Events/Past%20Meeting%20Resources/Building%20Resilience/Building%20Resilience%20meeting%20report.pdf>

In the sections that follow, we attempt to tell some of the story of IRNH through these inextricably linked aspects of the programme.

Managing the research

Large international, multi-disciplinary, multi-stakeholder, challenge-led projects like STREVA and EwF present a significant management challenge because of the diversity and geographic spread of the people and organisations and locations involved. ‘Working with difference’, be it in perspective, worldview, working practice, experience, values, priorities or ideas about how the project should be managed, has been necessary at every step. The significant unknowns that the teams have faced, particularly at the start (e.g. the nature of the institutional landscape and how the research disciplines would integrate), and the fact that the projects needed to be responsive to the contexts, which sometimes changed rapidly (as in the case of the 2015 Gorkha earthquake in Nepal), have added another layer of complexity. However, as one interviewee noted, the consequent need for a flexible, adaptive approach also enhanced the collective learning opportunities for those team members involved.

The proposal stage

The IRNH programme’s goal required that many of the people involved work in a way that was unfamiliar to them and one might argue that this had an impact on what the projects originally set out to do and how. This way of working (challenge-led, multidisciplinary, working in multiple countries, etc.) requires significant time and money, perhaps more than was available or originally budgeted for in the proposals in the view of some of the interviewees (although both consortia won additional funding). For example:

“We need to think more carefully about ensuring senior scientists have sufficient time in an experimental programme of this nature. We relied too much on goodwill to get things done and to be honest this relied on a few people working extremely hard to make it work at all.”

One interviewee made the point that there is a potential tension between what might be considered a competitive, ‘scientifically-excellent’ research proposal versus what might end up being an effective project that leads to positive societal impact. This might indicate that new metrics and ways of evaluation might be necessary to assess this type of proposal:

“If we were using the knowledge that we have now [and] putting in a proposal, we would allow more time for this type of research, realistically meaning fewer objectives over the lifetime of the project – would that be considered not sufficiently ambitious given that the metrics are usually based against what people do with fundamental single disciplinary science?...”

Another shed light on some of the difficulties in bringing non-traditional UKRI funding recipients (i.e. impact-focussed organisations that may or may not undertake academic research but are not universities or research centres) into these consortia because the standard research funding model used by the research councils is not compatible with their business model. This is a challenge that still needs to be addressed in the UK as new consortia responding to today's funding calls, e.g. the Global Challenges Research Fund (GCRF)², seek to involve non-traditional funding recipients in order to satisfy the requirements of future impact-focussed research calls. That said, the funding landscape in the UK has already changed much in the eight years since the IRNH programme began. There are more funding calls for IRNH-type research projects and the landscape is very gradually evolving to take account of the fact that standard funding models are not adequate for this way of working. However, one might argue that this could potentially lead to a situation where funding requirements (e.g. you must include physical scientists, social scientists and researchers from the arts and humanities) may end up driving the research and impact work, rather than the needs 'on the ground'.

In terms of what happened after funding was awarded and the projects were underway, several interviewees highlighted the value of creating or exploiting opportunities to build the consortia and their teams. For example, this interviewee spoke of the importance of team building right from the start for complex projects of this sort:

"Because you've got multiple objectives and in the early stages of a large complex project like this...some priority has to be given to building the team, as much as anything else, because if that isn't achieved then all of the subsequent activities are going to be at best precarious some way or other, because there may not be quite the kind of buy-in and commitment from everyone."

This type of relationship-building activity takes dedicated time and resources and needs to be balanced against the need for more focussed activities with smaller groups working together as the projects develop.

Communication

Given the complexity of the projects, good communication was crucial but did not always happen consistently. This is a challenge in any project and is exacerbated when people are based in different organisations, countries and time zones as STREVA and EwF have been. The projects used various methods to share information

² The Global Challenges Research Fund is a £1.5 billion fund announced by the UK Government in late 2015 to support cutting-edge disciplinary and interdisciplinary research to address challenges faced by developing countries.

between the team members including email groups, cloud-based systems and newsletters as well as the projects' websites. Project and programme workshops where people could interact, learn from each other and reflect on the research were considered to be really valuable by the interviewees. These forums allowed people to see how what they were doing fitted into the broader project objectives and increased the potential for a more multi or interdisciplinary approach to develop. One physical scientist said:

“If I wasn't actually working on a social science problem [with an awareness of what others were doing] I could place my own research in a framework that in some way connects into that, which was great.”

However, opportunities to reflect on the research process specifically (as recommended by Toomey et al., 2015) were not built into the design of either project. STREVA and EwF also organised several events that brought their international partners together. The five international partners (three working with EwF and two with STREVA) we interviewed for this paper all spoke of the value of these events for 'cross-partner learning' and sharing working practices. They expressed a strong desire for more opportunities to be able to learn from the other international partners involved in the programme:

“There wasn't really enough opportunity for us to really learn from one another. Because we were having the same goals in each country it would have been wonderful if we had a bit more chance to learn what were some of the good practices or what were some of the hiccups, so that we will be able to learn, in addition to what you were doing in different localities.”

The importance of flexibility

Taking a flexible approach in terms of both project management and allocating funds was important. It allowed the projects to respond to what was emerging in the contexts in which they were working and the relationships that were developing. However, this way of working was unfamiliar to many of the people involved in the programme:

“I was expecting to have some defined goals and given a task or a project to go and work on; and actually there was a lot more scope to find exciting things and just follow them up.”

There was capacity for flexibility at both a project and programme level albeit within the constraints of many of the researchers' teaching commitments, which limited when overseas working was possible. The UK researchers and international partners appreciated being able to take an adaptive, learning-type approach as a result of this flexibility. For example:

“Every six months I would say [to the programme staff], okay, here’s where we’re going and I think we need to reassign some of our resources from x to y. Can we have permission to do that? ... All these things I had to ask them to do and every single time they said, yes, go ahead, do it. So we were fortunate to be well supported in that way, and that’s what we needed, because everyone understood that we were trying to do something which hadn’t been done before and it was an experiment.”

The research councils typically have less interaction than this with the other projects they fund. However, this researcher’s experience suggests that this level of interaction can be very useful.

Programme integration

At the programme level, NERC and ESRC were keen that EwF and STREVA were well integrated in order to ‘maximise the synergies that arise’ from the connections (NERC-ESRC, 2011). The Strategic Advisor and KE fellows were an important part of the approach, for example, the KE fellows ran a series of ‘integrating workshops’ between 2014 and 2018 on topics that were of interest to both projects, and with the Strategic Advisor, organised a programme conference (Building Resilience to Geohazards in the Face of Uncertainty) at the Geological Society of London in 2017. The participants viewed these events positively but there was a general sense from the interviews that perhaps more could have been done to integrate the two projects (e.g. joint excursions to project sites). In terms of how that integration might be encouraged, one interviewee spoke of how sharing individual experiences and finding similarities and differences in those experiences felt like a *“genuine exchange and a listening to each other”* that could lead to productive integration of the projects. Funding for activities specifically to integrate the projects was suggested. However, it should be noted that there was also some resistance from researchers in the consortia for further integration activities too.

Reflections on the successes and challenges of the programme

While a systematic evaluation of the programme is outside the scope of this paper, we wanted to reflect on the programmes’ successes, and what did not work so well. There is, of course, a diversity in the way people view success of a programme of this type: for example, is success fulfilling objectives, drawing on the integration of disciplines, making interesting discoveries, creating impact, and/or moving the subject forward? Many of the interviewees stated that the most obvious measure of success meant achieving the objectives of a project, and for both STREVA and EwF, in general people felt – for the most part - that those original objectives had been met. Flexibility of the research process allowed both projects to add substance to the original objectives, add layers of

sophistication in terms of both single-disciplinary and integrative thinking and be able to take advantage of opportunities to explore research 'side-roads'.

"We were, in the end, prepared to be flexible and not feel beholden to the various goals and ambitions that we put in our original proposal. Because, of course, half of them were unworkable, half of them were unrealistic, and a whole load of other ones arrived opportunistically...during the project... which we took advantage of."

Collaborative working

A common theme to emerge across our reflection of the programme was the importance of good collaborative practice, both 'outwardly' and within project teams. A well-integrated core interdisciplinary team was deemed particularly important, both to support the functioning of the projects and to enrich the research.

"From the perspective of multi or interdisciplinary projects, I think success is actually managing to build a well-integrated working group who can work across disciplines in ways that are not only functional as opposed to dysfunctional, but importantly are also productive in a way that adds value that you wouldn't have realised or achieved had you been working in single disciplinary or narrowly bound disciplinary groups."

Within EwF and STREVA, this was often achieved through shared experiences of fieldwork affording space and time for researchers and project partners to get to know one another both professionally and personally. These shared 'landscapes of practice' (Wenger-Trayner et al., 2014) helped to facilitate dialogue between researchers across disciplines and offered a common space to share perspectives, knowledge and develop interdisciplinary learning:

"That degree of openness and willingness to both challenge and be challenged and that's been very, very helpful."

"Now in relation to...the collaborative work between the social science and the physical science researchers, I think what was very interesting and daunting for me was really the discussion – and if I may put it crudely – really the bantering that happens, because we see things from very different perspectives and we sometimes do things also very differently; and I think that this kind of differences generated a lot of interesting perspectives and it enriched the whole process of us putting this project together."

Creating space for that ‘banter’ (i.e. friendly informal exchanges between people) to occur is replicable, to a point; however this will vary from group to group and depend on the individuals involved. One interviewee suggested that more could have been done at the outset of the project to help catalyse relationship building:

“I think one of the things that we could have done in the beginning is really to do a bit more team building, so we spend a bit more time both formally and informally for us to be able to know one another better, where we are coming from professionally, meaning our research paradigms, and how things are being done differently.”

Broadening out to collaboration with overseas project partners, there were also examples of successful collaboration with project partners throughout the course of the research. Partners were often involved at the proposal stage and helped to shape the aims and objectives according to the needs of the overseas institutions and the communities they support. Early involvement of partners was usually facilitated by the existence of established relationships:

“One of the things that contributed to its success was some of the pre-existing relationships between some of the people who took part in the project and some of the researchers in particular, but also some of the very already well-established working relationships, some of the countries we’ve worked in and with, and that meant that it wasn’t starting from a blank sheet of paper and it wasn’t starting from a core and a bunch of people getting together simply because there was some money on the table and not having any strong connections with each other. And I think that mattered a lot.”

Throughout the programme, researchers and partners also reflected on the importance of cultivating those relationships continuously:

“It’s that kind of incremental dialogue with your partners that really matters; it’s being at a table to have those conversations consistently over a long period of time, that’s when it can be really useful.”

The existence of pre-established relationships with partners was not necessarily the case for all contexts, particularly Kazakhstan and China for EwF, and to an extent Colombia for STREVA. Collaboration was aided, in part, by in-country intermediaries, and significant time was spent in-country developing relationships with project partners. However, for both EwF and STREVA, spin-off projects have allowed for research to continue post-programme:

“I think it’s very evident that one of the impacts is how it has been able to attract further funding which we are still working on, we are coming to the end of another project...and this project is actually built

on from our previous experience in EwF. Without the EwF experience I do not think we could be where we are today in our second project, or the project that is a continuation of EwF; and we would not be able to, I think, get the money to begin with, and secondly, and also build on the previous experiences we've had and do things slightly differently.”

We will reflect on the importance of spin-off projects from the programme later in the paper.

Finally, some interviewees considered the process of collaborating with communities to be a success of the programme:

“The third success, I think has been in genuine collaboration with institutions, and particularly with communities....we've had a lot of interaction with stakeholders that's gone beyond the routine. Since the impact agenda³ has come onto the scene in research, a lot of stakeholder interaction type work has been fairly tokenistic. “

The success, is due in part to the conduct of researchers when working at community level. This goes beyond adhering to ethical guidelines; researchers had to be sensitive to the fact that the communities they were working were at risk from the impact of natural hazards. Attempts to avoid any sense of being extractive were made by regular and extensive interaction with stakeholders (particularly community members). Returning to visit the same individuals, villages, and community groups, even for a chat, was not only a trust-building action, but also offered space and time for people to make suggestions about the research:

“And by extension, listening also to the communities themselves and what they say. I think there is a genuine effort to do that and I think if projects want to work in communities, like STREVA did, did I think it's important to listen to what people have to say, and directly implement some of the suggestions that they have”.

Often these suggestions led to creative ways of working with communities, particularly in terms of feedback and exchange. For STREVA, this included the development of oral history films (Hicks et al., 2017), collaborative workshops (e.g. Figure 2), and artistic presentations. In Nepal, EwF developed low-tech approaches for monitoring slopes in collaboration with concerned householders, and are continuing to support the

³ See <https://www.ukri.org/innovation/excellence-with-impact/>

communities involved. EwF also worked with community members and a visual anthropologist in Kazakhstan to capture people's understandings and experiences of earthquakes and related hazards.



Figure 2. Vigias (volunteer volcano watchers) in Ecuador undertaking a participatory exercise mapping evacuation routes from their town (workshop in June 2013; photo provided by A. Hicks).



Figure. 3 Implementing low-tech approaches to monitoring slopes in Nepal (photo provided by A. Densmore)

Outputs

The projects have produced a variety of outputs including academic papers, films and policy material. The academic outputs from the programme have been numerous (<http://streva.ac.uk/our-outputs/> and <http://ewf.nerc.ac.uk/publications/>) and as of August 2018, 153 papers have been published by the programme in 43 journals. The majority of these publications have a focus on physical science. Less than 10% have been interdisciplinary. However, there is a clear time lag between production of single disciplinary and interdisciplinary outputs. In STREVA for example, the truly interdisciplinary academic outputs took far longer to develop, as much of the integration in thinking and actions came towards the latter half of the project (Fig. 4).

“I think the richness of the outputs that comes from working together across disciplines will take longer to develop and mature, but I think they’ll be longer lasting as a consequence.”

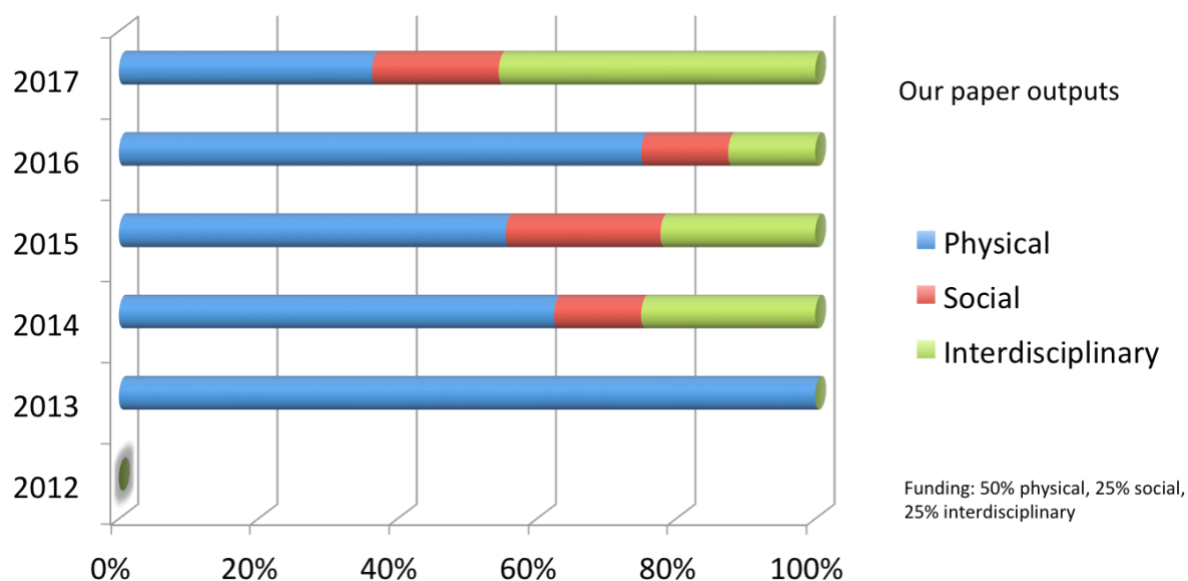


Figure 4. STREVA outputs over time. Figure supplied by Jenni Barclay.

In several cases, the academic outputs had impact beyond academic ‘space’, with data and evidence being used by project partners to support decision making. This is discussed further in the legacy section below.

Success in terms of outputs is also manifest as spin-off projects during the course of the programme, usually funded by sources beyond those held by the programme. For STREVA, one particularly successful spin-off project was the development of experiential films designed to record oral histories of eruptions in both St Vincent

and Colombia. This came at the request of the communities themselves, and community members became the leading ‘actors’ in the films, guiding the audience (the communities) through their experience of eruptions. The films were screened in communities in both countries; which helped to generate dialogue around volcanic hazard and risk, and actions to reduce it. The films are now embedded in the risk communication strategies of both the Servicio Geológico Colombiano and the University of the West Indies Seismic Research Centre. They have been widely viewed around the world, and have led to new research and new films produced in other contexts.

For EwF, members of the team secured additional funding from the UK Department for International Development’s South Asia Research Hub to undertake a review of Nepal’s 9 Minimum Characteristics of a Disaster Resilient Community. This was for the Government of Nepal and international development partners. The review, which explored the outputs and outcomes associated with the 9 Minimum Characteristics across 24 case study communities, led to a series of recommendations which are currently informing DRR policy and practice in Nepal, including the new Local Disaster and Climate Resilience Planning guidelines and the British Red Cross’ Strengthening Urban Resilience programme⁴.

Legacy – what happens after the IRNH programme ends?

EwF and STREVA were expected by the funders to have an impact on decision making for risk reduction and resilience building (illustrated by the examples given in the previous section), undertake capacity building for scientists in earthquake-prone and volcanic regions (something that is “increasingly an inextricable component of science funding” - Hewitson, 2015, p 497), and allow the UK to lead research in new science areas (NERC-ESRC, 2011). Each of these aspects is an entry point into a set of longer-term processes in the UK and partner countries that will outlive the programme (e.g. the advancement of knowledge, resilience, the evolution of research culture, relationships between people or organisations, and the lives of the individuals involved in or affected by the programme). However, this quote from one of the local partners illustrates how even if everything ‘goes right’, legacy will not necessarily last without continued effort, and this must be borne in mind from the start of a project:

“... I think that the only way that projects like this can go on in the future, is if people see the real strength that the STREVA project helped us to have with our group of vigias [community volcano watchers]. That’s now

⁴ More information can be found here <https://www.gov.uk/dfid-research-outputs/review-of-the-nine-minimum-characteristics-of-a-disaster-resilient-community-in-nepal-research-report>

translated to the vigia group becoming a reference at an international level. But we can't forget about it. Even though Tungurahua [a case study volcano in the project] is dying down, our goal...is to try to maintain the cohesiveness, it doesn't only depend on us, it depends on the volcano, it depends on them, and it depends on having to be able to maintain the radio system, and our observatory there."

To focus our consideration of the legacy of the IRNH programme, we concentrate on three aspects: the relationships and networks that have developed, the research legacy, and capacity development. Although it is too early to have a complete understanding of what the legacy of the projects is likely to be, the interviews and programme documentation do give an indication of what may happen after the IRNH programme and its projects end.

Relationships and networks

In all the interviews, relationships and partnerships, be they between researchers, with local scientific researchers, stakeholders or policymakers, or research disciplines, are seen to be as important as the research itself when it comes to creating a lasting legacy and that this should be acknowledged by everyone involved, particularly the funders. For example:

"There needs to be more recognition of all the other stuff that you need to do as well as the research, and I think the more of the other stuff that you can do, as well as the research, like the kind of spending time together and network building, practical engagement on the ground, building relationships with some organisations, bringing organisations within different networks together, I think all of that will improve the sustainability of whatever is started through projects like this."

Investing in these relationships was seen to be a vital part of the approach that both projects took and must be adequately resourced in order to lay the groundwork for a positive legacy. There were a number of examples in the interviews where the value of investing time and effort in building positive, respectful relationships with communities has led to research, and approaches to engagement, that are influenced by an understanding of the communities' concerns and the challenges they face. This in turn is shaping how hazards are understood and managed in the communities, which is likely to have an impact after the programme ends. For example:

"I think a lot of the data that was collected from STREVA is being used to inform how we deal with hazards, certainly in the future in the region. One of the things that came out is the whole use of... scenarios that they used before in other hazard contexts. We've used scenarios over and over again in STREVA in trying to deal with

how people deal with the hazards. It is now becoming part of how we deal with training disaster managers and fleshing out disaster management plans.”

In the countries where STREVA has worked, this way of working has also led to *“a very positive impression in the communities of scientists from outside the territory coming into the territory”*. The outputs (community films) *“can be used over and over to heighten awareness”* and underline the importance of positive relationships in creating the potential for the long-term impact and lasting legacy of science-led projects.

However, most of the interviewees did express significant concern that there were no funds directly connected to the IRNH programme available to sustain the partnerships developed during the projects and *“to keep the conversations alive even though the project itself has finished”*. Furthermore, some expressed a strongly felt concern that overseas partners’ expectations had been raised and that the projects coming to a relatively abrupt end would have a negative impact on their partners, and damage the relationships between the UK-based researchers and their partners. The UK’s current Global Challenges Research Fund provides opportunities for undertaking international, interdisciplinary, challenge-led resilience research has provided funding in its initial phase for building new networks (acknowledging that strong relationships and networks facilitate co-developed research). However, funding to specifically support existing networks like those developed through the IRNH Programme has not been available. A number of people said that the lack of continuing support was a source of frustration. Opportunities to fund existing networks do exist though. Both EwF and STREVA have led to spin-off research projects that build on the collaborations established by the consortia (see section on success) and do help to sustain existing partnerships and networks. Even so, many of the interviewees thought there should be dedicated funding within the IRNH space to support the networks and relationships that have been developed. This highlights the importance of investing in the legacy of the projects as much as in the projects themselves.

Research legacy

According to the entries made to researchfish®, as of August 2018, four books, one book chapter and 288 peer-reviewed journal papers have been published by IRNH researchers in both the physical and social sciences. The academic legacy of IRNH is clearly substantial and there have been major advancements in the understanding of geohazards and resilience in the regions where the projects were working. Beyond this, the research findings have been used widely in decision making. For example, in preparing earthquake scenarios for decision making in China, DRR and reconstruction activities in Nepal, public information campaigns in Kazakhstan, risk reduction

strategies for volcanic hazards in Colombia, Ecuador and the Lesser Antilles, and development of household-level emergency plans in St Vincent.

Other outputs have included working papers (including the product of a ‘write-shop’ held in China by EwF that brought together different groups working on building earthquake resilience, see Young et al., 2015), community-based films (Hicks et al., 2018) and pieces of music⁵. Both projects have also produced databases, models, tools and software. Researchers have taken part in working groups and expert panels (e.g. community hazard assessment procedures by the National Reconstruction Authority, Nepal) and run numerous workshops (e.g. STREVA’s ‘forensic’ workshops in Montserrat, Ecuador, Colombia and St Vincent that brought scientists, communities and other decision makers together to reflect on past volcanic crises and what can be learned from this). People from the projects have also given talks to decision makers in the partner countries and the UK, participated in advisory committees and provided various technical services (e.g. lahar modelling courses in Ecuador and Colombia and seismic data analysis training in Kazakhstan).

Capacity development

We argue that a legacy of the IRNH programme will be from the projects’ capacity development activities. In the discussion that follows, we adopt the UNISDR definition of capacity development, i.e. “the process by which people, organisations and society systematically stimulate and develop their capacities over time to achieve social and economic goals” and not just for the scientists in the partner countries, which was the original aim in the original call. This is because it is clear that there have been various types of capacity development due to EwF and STREVA that will outlast the projects. Therefore, in this section, we focus on the development of scientific capacity in the partner countries and the development of capacity in the UK to undertake inter- or transdisciplinary research on resilience.

Scientists in the partner countries

Both EwF and STREVA have sought to contribute to scientific capacity building in the countries where they have been working. Local scientific expertise to monitor and assess hazards, and provide information to decision makers is vital because local scientists can be responsive to the needs of a particular context in a way that a scientist from elsewhere may not be able. It is interesting to note that from a global perspective, most scientific capacity

⁵For more information go to <http://www.st-annes.ox.ac.uk/about/news/item/article/volcanoes-performance-by-st-annes>

building efforts have focused on disciplines like the geosciences (Aitsi-Selmi et al., 2016) although relatively few assessments of these endeavours appear to have been published. The projects have undertaken various activities including workshops (e.g. a summer school for young scientists organised by the researchers from EwF, and involved people from the wider EwF partnership, scientists in STREVA developed lahar modelling tools and provided training on these), fieldwork and work placements.

There was no provision for funding studentships directly through the programme but both projects have been able to find ways to support young scientists in the countries where they have been working, e.g. through supporting applications to do Masters and PhD studentships in the UK and funding conference attendance. These people then take the knowledge and experience they gain with them into other roles as their career develops. However, there is nothing to say that if 'capacity gets built, capacity stays built' (Hewitson, 2015, p 498) without follow-up engagement. From the point of view of UNDP (2009), capacity development 'must bring about transformation that is generated and sustained over time from within' (ibid., p 5) and there were indications from the interviews that sustained 'transformation' (ibid., p5) may not always be possible because of wider issues. One interviewee highlighted that one of the challenges when it comes to building geoscience capacity in some countries is that certain career paths may be more appealing to young scientists than hazard-related work because the salaries offered by some sectors will be higher (e.g. in the oil industry). Tackling the organisational, institutional and financial barriers to cultivating and sustaining local geoscience capacity is clearly an issue that needs to be addressed in the longer term for in order for science and scientists to effectively support DRR and contribute to resilience-building processes. However, as this interviewee went on to say:

"It's actually getting at people in other subjects, those who might be city planners or economists or politicians or whatever, they're probably the people to really try and influence."

This highlights the need for a more integrated way of working between sectors and disciplines to maximise the potential value that science can bring to decision making for DRR and resilience in the long term, and where projects like EwF and STREVA may achieve a lasting legacy. Further research is necessary to explore specific approaches to capacity building that the projects employed and how outcomes will be sustained.

Scientists in the UK

A Community Survey undertaken for the IRNH programme in 2011 indicated that there was some resistance amongst the UK's NERC-facing research community to challenge-led interdisciplinary research

(Sammonds, 2018). In the interviews for this paper, we have explored how the way people work has been influenced by their involvement with EwF or STREVA.

It is clear that as a result of the IRNH programme, there is now a community of physical and social science researchers in the UK who have a deep understanding of what this type of research requires to be effective. Most people interviewed for this study said that what they do now or how they think about their research has evolved as a result of their experiences with the IRNH programme. For example, through being exposed to new ways of working or collaborating with different groups, they are thinking beyond their core research interests, asking different questions because of this engagement, considering the potential implications of their work as they develop their ideas or recognise the importance of early engagement with stakeholders. One interviewee's experience was of the power of integrating local experience of volcanic hazard with their scientific knowledge:

“Then discovering on St Vincent, there's a huge appetite within the local community that actually hearing about parts of their history with which they're very familiar, about which they have their own stories and perspectives, and then realising actually these two sets of stories bring these two sets of approaches together, it's actually a very powerful way of looking at and thinking about what happened during previous eruptions.”

In a small number of cases, even if their involvement had not changed the way a person worked, they still valued it as an opportunity to see how researchers from other disciplines work or to be asked questions that they otherwise would not be.

One interviewee had the impression that the way in which the physical scientists involved in STREVA now thought about risk had evolved away from “measures of hazard, exposure, physical vulnerability” and that they now had a deeper appreciation for the importance of the societal aspects of risk. They expressed a hope that in time, it might be possible to “embed these ideas” within the wider volcanological community so that it might become a more mainstream view. In this way, contributing to a shift in how this group conceives risk may also be part of STREVA's legacy.

Final thoughts

The Sendai Framework sets out where and how science and the scientific community can contribute to understanding, managing and reducing disaster risk. This snapshot of the IRNH programme illustrates some of the complexity and hard work that lies behind these words and what is needed to support this. In terms of funding and project management, it is important to recognise that working on challenge-led interdisciplinary projects often

requires time, money and flexibility in order to be responsive to the local context. The successes include development of the interdisciplinary 'process', realising project objectives and developing partnerships, and are due to factors including effective collaboration at team level, with project partners and with stakeholders. However, more detailed investigation of the relationships between those involved in the research and how these influenced the way in which the projects were able to contribute to local resilience-building processes is necessary. Although it is too early to make a detailed assessment of the longer term legacy of Earthquakes without Frontiers and Strengthening Resilience in Volcanic Areas, the projects demonstrate that there are clearly ways to maximise the potential for positive impact after they end. It is vital that the lessons learned during the IRNH programme lead to actions that create an enabling environment for innovative research in collaboration with relevant stakeholders and policy makers to evolve and thrive.

Three of the main challenges that have emerged from our reflection on the IRNH programme that should be tackled when doing this kind of research are given below. They strongly echo what is already reported in the literature on interdisciplinary research (e.g. Marzano et al., 2006; Lyall et al., 2011). We also provide suggestions for how these challenges might be tackled for both researchers and funders, since funders' support is vital if this kind of research to achieve its potential (Lyall et al., 2013).

Challenge 1: developing a culture of openness, listening and acknowledgement of the different ways of seeing and experiencing the world amongst the whole team.

This type of working requires diverse groups to come together, whether that be across disciplines, countries and/or sectors. Teams will have a diversity of skillsets, working styles and personalities and there is a need to develop ways that people can work together effectively and ensure those traits and working approaches are complementary. A shared vision and strong leadership is required, as well as sufficient time and money to support project communication and cultivate the necessary partnerships.

Recommendation for researchers: accept the uncertainty and possible unease of working outside of one's comfort zone, as rewards exist in the form of potential opportunities for research that can have significant positive societal impact. Given the complexity of this kind of working, be realistic about what can be achieved, especially in very time-limited projects.

Recommendation for funders: proposals should be assessed not only on the basis of their academic and scientific strengths, but also on their plans for facilitating and managing inter- or transdisciplinary research. Given the complexity of this kind of working, be realistic about what can be achieved, especially in very time-limited projects.

Challenge 2: Ensuring that there is an appropriate framework in place to support flexibility in a project so that it can respond to the specific needs of the context and the team's evolving understanding of it.

Recommendation for researchers: Be open to learning from mistakes, changing direction and responding creatively to the dynamics of the context. Actively participate in and/or create opportunities for communication with colleagues, especially if they are based in other organisations or countries.

Recommendation for funders: Stay engaged with the projects after funding has been awarded to maintain awareness of the challenges and potential opportunities researchers encounter, and help them to respond to these. Use the lessons learned to guide good practice on setting up and running challenge-led programmes.

Challenge 3: Funding for a research programme is generally finite. Although opportunities for funding complementary research projects that help to sustain partnerships and networks may arise, the potential negative impact on local partners of research funding 'cliff edges' has to be managed.

Recommendation for researchers: From the very beginning of the project, give consideration to how any networks, partnerships or activities can be sustained in the longer term (if this is something that all parties agree would be useful) and consider the potential impact on these relationships if follow-on funding is not found.

Recommendation for funders: Consider programme legacy when setting out on to fund research into increasing resilience.

We hope that the lessons learned by the IRNH Programme and the recommendations that have resulted will be of value to others' efforts to undertake challenge-led disciplinary, interdisciplinary and transdisciplinary research to support DRR and contribute to resilience-building.

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