Earthquakes without Frontiers: Final Report.

28th February, 2019

EwF partners from NSET in Nepal, Ranjan Dhungel (L) and Amod Dixit (R), with Kanatbek Abdrakhmatov (centre, from the Institute of Seismology, Kyrgyzstan) in the Chon-Aksu Valley of Kyrgyzstan, examining the faulting from the 1911 earthquake that damaged Almaty (Kazakhstan) beyond the distant mountains.

Contributors

The report was prepared by Philip England, James Jackson, John Young. A very large number of people contributed to this project, and thus directly or indirectly to this report. Key contributors were:

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1. Introduction

This is a report on the Earthquakes Without Frontiers (EwF) Project. The project included detailed fieldwork in collaboration with local researchers and policymakers focussed on three case-study areas: Nepal and India (Bihar State), China and Kazakhstan, as well as knowledge-sharing and other interactions with researchers and policymakers elsewhere in Central Asia, Iran, India and Southern Europe. It adopted an experimental transdisciplinary approach – bringing together natural and social scientists, policy makers and practitioners, to develop practical, research-informed approaches to increase resilience to earthquakes.

The report is based on a final project workshop in Oxford in July 2018, which brought together twenty researchers from across most of the UK-based organisations involved in the project to discuss the outcomes and lessons. Many more project participants had contributed to drafting three “performance stories”, one about each of the major project country programmes. The authors would like to expresss their gratitude for the contributions of all participants, but take full responsibility for this attempt to summarise the conclusions.

Section 2 outlines the overall problem and objectives of the project; Section 3 the specific challenges in each area; Section 4 describes the different approaches in each area; Section 5 an overview of the impact in each area, and globally; Section 6 the overall outcomes; and Section 7 the lessons learned across the project as a whole. A list of the organisations involved is provided in Annex 1, the closing statements of a session of Earthquake Hazard and Risk at the 32nd National and the 1st International Geosciences Congress in Tabriz, Iran in February 2014 in Annex 2, and all publications up to 2018 in Annex 3.

2. The Problem

The fundamental goal of this project was to increase resilience to earthquakes across the Alpine-Himalayan region through advances in understanding of the earthquake hazards and risks, of their societal contexts, and of risk reduction policy and policymaking.

Approximately 2 million people died in earthquakes during the past 100 years, over two-thirds of whom were in low- and middle-income countries. The attendant damage to essential infrastructure, crippling of local economies, disruption of livelihoods, and mass displacements of people often set back development in the affected regions by decades. The capacity of the economically more developed societies to resist earthquakes is already at an impressively high level, and continues to improve. In contrast, earthquake risks in counties that are less economically developed are worsening ever more rapidly as vast populations migrate into vulnerable cities, while rural populations remain in highly vulnerable dwellings. It is estimated that by 2050 about 2 billion people in the Global South world will be exposed to serious earthquake risk.

EwF was funded, under the NERC/ESRC programme *Increasing Resilience to Natural Hazards* (IRNH), to carry out research that would *(i)* better determine the distribution of the earthquake hazards in Eurasia, which are largely unknown in the vast regions at risk; *(ii)* identify pathways to increased resilience in the very different socio-economic environments and regimes of governance across the region; *(iii)* leave a long-term legacy through capacity building and the establishment of a well-networked international partnership to consolidate and disseminate the results of the programme.

EwF was founded on strong existing relationships of the research team with individuals and organisations working on different aspects of earthquake resilience in a range of earthquake-prone countries. The project was designed to address specific challenges in each country, to bring together researchers, policymakers and practitioners, and to strengthen national and international networks. The way the project evolved in each country was shaped by the context, by existing relationships, and by specific opportunities that emerged during the life of the project, most notably the 2015 earthquake in Nepal.

3. Regional Contexts

We discuss EwF's activities in five broad geographical groupings, which differ greatly in the challenges that are posed by their states of scientific knowledge, their relations between science and policy, and by their systems of governance. While most of the fieldwork took place in Nepal, India (Bihar State), Central Asia and China, colleagues from Iran, Southern Europe and the Mediterranean also brought experience from their regions, which proved to be extremely influential.

Nepal and Bihar

Nepal is undergoing a complex political transition following a decade-long civil conflict (1996-2006)[1]. Unsurprisingly, therefore, while earthquake and landslide risks were recognised by communities, policy makers and practitioners, disaster risk reduction was sidelined, at least within government. Until September 2017, Nepal was working from a disaster management act of 1982, with a focus on disaster response and recovery. Some progress in disaster risk reduction was nevertheless taking place, through both local and international efforts. Prominent among local initiatives is a national NGO, NSET-Nepal, whose approach to risk reduction is based on well-informed scientific understanding allied to architectural and engineering solutions that are appropriate to the low-income context.

Bihar State, while subject to broadly similar earthquake hazards, had approached the governance of earthquake risk reduction from a fundamentally different perspective. The presence of strong federal and state governments, and notably the activity of the Bihar State Disaster Management Authority, meant that earthquake risk is governed in a much more top-down and centralised way. There is limited involvement of national or international NGOs and some substantial efforts at organising community-based risk reduction efforts were already underway at the outset of the project. More broadly, India has a strong educational tradition, with a number of good young earthquake and social scientists who have been trained internationally at PhD level, and have returned to positions of leadership in universities and state government.

China

Responsibility for earthquake risk mitigation was[2] divided between the Ministry of Civil Affairs (MCA) and the China Earthquake Administration (CEA), a ministry-level organization with responsibility for the science. Following the 2008 Wenchuan earthquake (80,000 deaths) there was a shift in emphasis from post-disaster response to pre-disaster mitigation, and a move away from linking public safety to short-termearthquake prediction . There remain, however, two fundamental divides: *(i)* in communication of scientist knowledge to policymakers and communities and *(ii)* between the top-down policies and their implementation, which is from the bottom up.

Central Asia

The region has inherited a hierarchical system that pervades government, scientific institutions, and education. Such Earth Science education as exists is largely directed towards exploitation of hydrocarbons, minerals and other resources, and there is little understanding of the modern aspects of earthquake-hazard science. A significant additional problem is the isolation of scientific and academic staff from modern scientific literature because of unfamiliarity with English. When we began the project, the predominant view was that earthquakes are predictable, so that governments need take no action other than to demand short-term predictions from scientists. This misconception represented the principal obstacle to progress; a system had evolved in which *(a)* no action was taken on mitigation; *(b)* such

[1] Significant changes to the government architecture are now underway following the ratification of the new constitution, federal restructuring, and local elections for the first time in 20 years.

[2] The situation changed totally towards the end of the project, with the creation of a new Ministry with overarching responsibility for all emergencies. The implications of this change are unclear at the time of writing.

maps of seismic hazard as existed were decades old and spectacularly incorrect; *(c)* research in recognizably modern or innovative directions was rarely encouraged by institutional leaders – though notable exceptions include our two local partners Kanatbek Abdrakhmatov and Natalaya Mikhailova (see below), whose leadership and encouragement of their younger staff was inspirational.

Iran and India

Iran's small earthquake-science community is well connected internationally. Another positive aspect, unusual in the region as a whole, is a strong educational tradition and a widespread and increasing competence in English. There is no shortage of clever, motivated young people, who usually benefit from responsible and encouraging leadership by scientific patrons. At a personal level, and once in the country, there are no barriers to travel or engagement. Global political problems repeatedly cause complications in access, but our 40 years' experience of working in Iran has taught us that these problems are transient, and that there are many ways to work around them. Indeed, we suspect that our engagement with Iran, through thick and thin, has helped to persuade partners from other countries that EwF represents a genuine long-term commitment to reduce earthquake disasters across Eurasia.

India also has a strong educational tradition, with several good young earthquake scientists who have been trained abroad at PhD level, and have returned to positions of leadership in universities. There are, however, great financial barriers to progress; funding is far below the level that good scientists could make effective use of. Earthquake resilience is managed by state-level Disaster Management Authorities, some of which are enlightened and creative, but there are barriers to coordination or sharing of experience between them. The formal processes for research permits are prolonged, difficult, and uncertain.

4. The Approach

In each area, the first phase of the project was an iterative process, in collaboration with our local colleagues, which characterised the state of knowledge about earthquake hazard and risk, and the pertinent political and socio-economic landscapes. Then we co-developed a programme of research and policy engagement. We subsequently carried out extensive investigations of active faulting, tsunami hazard, and landslide hazard in Central Asia, China, the Eastern Mediterranean, Iran, India, and Southern Europe. Concurrently, we co-developed research, exploring: the governance, both formal and informal, of disasters and disaster risk; local approaches to earthquakes and their secondary hazards; and the potential to integrate local and international knowledge to produce effective strategies for resilience to earthquake disaster. The evolution of work in each area was affected by social-cultural contexts, but was also substantially influenced by existing relationships with our local partners and by the topics of importance and interest to them. These relationships and the evolution of the work are outlined below.

Nepal and Bihar

The UK EwF team already had good relationships with key stakeholders in Nepal, most notably NSET-Nepal, with whom they had been working for a number of years. UK EwF personnel focusing on Nepal already had contact with the Bihar State Disaster Management Authority in India, as a natural extension of the hazards posed by earthquakes in the Himalaya, which affect both Nepal and India. Earthquake scientists based in other parts of India joined the EwF partnerships three years after its start, assisted by a supplementary NERC IOF grant that allowed us to build upon existing relationships (of 15+ years) with young, UK-trained, Indian seismologists.

Following the project launch meeting in Kathmandu in January 2013, and subsequent discussions with partners in Nepal including the newly formed Nepal Risk Reduction Consortium, the research team initially agreed to work towards *(i)* an in-depth understanding of how earthquake risk is governed at the national and sub-national levels in the context of a post-conflict transitional state; *(ii)* a better understanding of how householders perceive and

respond to earthquake hazard and risk in the context of a wider set of processes of social, political and economic transformation; *(iii)* an exploration of the current and potential use of earthquake and landslide science in DRR planning in Nepal; and *(iv)* the development of simple rules for landslide hazard assessment for use at the community scale, in the absence of specialist knowledge or technical capacity.

Working closely with existing partners, the team undertook an in-depth study of the national and sub-national governance arrangements for earthquake-risk reduction, including a comparative study between Nepal and Bihar. Building on this, research was undertaken to explore how science was informing DRR activities in Nepal and future opportunities for knowledge integration. Recommendations included: national level planning, for example through scenario development and more fine-grained risk mapping to assist in the prioritisation of locations for DRR interventions; and local (community) level disaster risk management planning. Research was subsequently undertaken on the geomorphic effects of large earthquakes and how they trigger landslides, and on community-level perceptions of earthquake and landslide risk. This revealed an urgent need to develop approaches linking national and local-level resilience and response efforts, and to enable local communities to assess the local landslide risk and develop local mitigation options, which met their livelihood needs. The Gorkha earthquake in April 2015 threw these issues into sharp focus, and the immediate response and longer-term recovery provided opportunities to share our learning around the risks posed by secondary landslides, and the implications for householders living with, and the government and NGO stakeholders managing, an evolving risk landscape. These are described in more detail in the next section.

China

At the start of the project the UK EwF team had several longstanding relationships and programmes of work with different, but unconnected stakeholders working on earthquake resilience issues. These included: discussions on geology and seismology with the China Earthquake Administration; work on education and post-earthquake recovery with universities, social work organisations, and NGOs in Beijing, Chengdu and Xi'an; and work with development policy organisations in Beijing. A key aim was to bring these different stakeholders together.

The project began with two coupled goals. The first was to increase knowledge about the distribution of active faults, their rates of slip, and the magnitudes of historical earthquakes on them. We were asked by the CEA to focus our attention on the Weihe Basin in Shaanxi Province, both because of its geological affinities with other areas, particularly Greece, with which the EwF team is familiar, and because this was the region affected by the 1556 Huaxian earthquake, which resulted in the greatest number of fatalities (>800,000) ever recorded. The geological fieldwork was successful in identifying the major faults of the region, and in making some progress towards estimating time intervals between earthquakes on the major faults. Those intervals are long (several thousand years) which poses challenges for further work. A significant outcome of the forensic geological work – which makes further work on time intervals an important priority – is that the magnitudes previously calculated for historical earthquakes are significant over-estimates. This means that the impacts of an earthquake of given size will be greater and – for the known rate of strain across the region – devastating earthquakes will be more frequent than previously believed.

The second goal was to work with local partners to identify and evaluate possible models for increasing resilience to earthquakes, at the community, provincial, and national levels. Initially, efforts were concentrated on community-based DRR research. Although there was interest from provincial and central government, and from an NGO with strong links to the government, this enterprise proved very labour-intensive and produced few generally-applicable results because of language difficulties and indifference of community leaders to the earthquake risks.

However, the transdisciplinary work with different stakeholders at national and local level generated interest among all stakeholders to learn more about what the others were doing and this led, in April 2015, to a workshop in Xi'an, which brought together national and international physical and social scientists, and staff from the NGOs, to capture and share

information about many aspects of earthquake disaster risk reduction. This resulted in the publication *Pathways to Earthquake Resilience in China* (ODI 2015). That meeting coincided with a call for proposals for further work on earthquake resilience in China to be funded by NERC, ESRC, and the China National Natural Science Foundation. It also followed closely after an international EwF workshop in Nepal, which brought Chinese EwF partners into contact with partners in other countries. These two events resulted in further work, which is described under impacts below.

Central Asia

At the start of the EwF project, our relationships in Central Asia were rudimentary. Our principal and most effective contact was the Director of the Institute of Seismology in Bishkek (Kyrgyzstan), Prof Kanatbek Abdrakhmatov, an excellent paleoseismologist in his own right, and one of the few Soviet-trained Earth scientists resident in central Asia with a scientific profile in the west. He is greatly respected throughout the region and opened doors for us, facilitated permissions, and accompanied us in the field, throughout Kazakhstan and Kyrgyzstan. In Kazakhstan we were also greatly helped by the Director of the Kazakh National Data Center, Dr Natalaya Mikhailova, who was persistently supportive and encouraging. These two patrons were invaluable, both in guiding us through the rapidly-shifting landscape of Kazakh educational and government institutions, and in causing us to be taken seriously by Kazakhs we met, through our association with them. They were central to all we achieved involving earthquake science in Kazakhstan and Kyrgyzstan.

By contrast, at the start of the project, we had no such essential contact for the social sciences. These links had to be forged over time and repeated field visits before identifying the Red Crescent Society of Kazakhstan as our main partner. Yelena Kim and Rustem Mustafin, its General and Deputy Director-General respectively, and staff both in the national and regional offices were instrumental in facilitating our research projects in Almaty and South Kazakhstan oblasts. In Zhambyl oblast, our principal partner was Mukhan Baitemirov at КазНИИСА (Kazakh Scientific Research and Design Institute of Construction and Architecture – Taraz City branch) and Taraz State University. Subsequently, more than 10 field trips explored: how disaster risk is governed in Kazakhstan from the nomadic past, through the Soviet era to the present day; community attitudes towards earthquakes and approaches to disaster-risk reduction (DRR) in rural Kazakhstan; the state of the local housing stock in provincial urban centres; and the role of formal and informal civil society organisations outside the major cities in community organisation and risk management. We also involved our research and practitioner partners from Nepal who were able to share their earthquake engineering knowledge and expertise with local communities.

A high point in 2016 was a three-day conference in Almaty co-hosted by EwF, the Institute of Seismology and the Almaty Akimat's (Mayor's) office and co-sponsored by the Yessenov Foundation, a particularly enlightened Kazakh educational charity. This brought national and international scientists and earthquake DRR practitioners together. At the meeting, the practical issues of public awareness and education on earthquakes and seismic hazard were discussed along with the dangers in allowing any belief in short-term prediction to be linked to policy on public safety, leading to some significant changes in attitudes among senior Kazakh scientists as outlined below under impacts.

Iran, Southern Europe, and the Mediterranean

Our involvement with Iran was critical for the EwF project. We had existing long-term relationships stretching back almost 40 years with excellent scientists in the Geological Survey of Iran, who are also charged with advising their government on earthquake resilience and public safety. These Iranians had well-established and respected international reputations in their own right, often involving collaborative scientific work and publications with UK EwF personnel, and they were essential to showing other countries what can be achieved through long-term partnership and trust. They were also highly effective ambassadors for the EwF approach at meetings in Italy, Kathmandu, Almaty, and Bishkek.

UK EwF personnel have worked extensively on the tectonics of Southern Europe and the Mediterranean since the 1970s. When the project started, we had existing long-term

collaborative relations with earth scientists in Greece and Italy, covering faulting, tectonics, and seismic hazard and – in the case of Greece – tsunami hazard. Those scientists contributed substantially by sharing their experience with our partners in developing and emerging countries, especially in Kazakhstan and Albania. In particular, our Italian colleagues were caught up in the post-L'Aquila-earthquake trial, and their experience, demonstrating the consequences of allowing the public to build an expectation that short-term earthquake prediction will protect them, made a powerful impression on our partners in central Asia. At the same time, our European colleagues also made it plain that EwF offered unique advantages to their own well-established organizations, because of its interdisciplinary and international nature.

5. Impacts

Assessing the impact of a large complex project like EwF is difficult. As is described above, the fieldwork in each country took place in contexts that were changing very fast, and the rapid exchange of knowledge and experience between participants at national and international meetings often led to unexpected developments. We discuss impacts at two levels: first as new contributions to knowledge, secondly as changes in people's understanding or attitudes, ways of thinking about earthquake resilience, and new processes, systems and policies. EwF has made a substantial contribution to knowledge through more than 80 papers in leading international journals, co-authored with in-country partners; these are listed at the end of this report. The most important impacts in each area and internationally are summarized below.

Nepal and Bihar

Although the devastating 25 April 2015 Gorkha, Nepal, earthquake introduced a step change in our approach (including, as is described below, in China), the EwF project was already having success through collaboration with NSET-Nepal, DFID Nepal, and the UN-initiated Nepal Risk Reduction Consortium. Following the 2015 earthquake, EwF researchers gave over 60 interviews on radio and TV and provided written material for media articles. Members of the research team also briefed the UK Government Chief Scientist and the DFID Chief Scientist, and provided daily input to SAGE and COBR. We were able to bring swiftly and effectively to the attention of the relevant bodies that this had been only "half an earthquake". The rupture stopped well below the surface and a further earthquake is expected to occur at shallower depth at an unknown time in the future; note that this future earthquake would be of comparable size to the 2015 earthquake, not merely an aftershock. Although this expected earthquake is yet to occur, in the immediate aftermath of the April 2015 earthquake it was valuable to know of a hazard that could have had a major impact on relief and recovery efforts. DFID and NERC acted extremely swiftly to arrange subsidiary funding for a collaborative seismological study with Indian and Nepalese seismologists, which allowed us to monitor the evolving situation over the following three years. The Bihar SDMA helped us deploy a seismic network to monitor aftershocks as part of this collaboration. DFID and NERC also supported a collaborative study with the British Geological Survey to map and monitor the landslides and unstable ground triggered by the 2015 earthquakes.

EwF researchers provided advice to the UN Resident Coordinator's office on expected levels of damage in different parts of Nepal, continuing and potential threats in the aftermath earthquake and major aftershocks, and on hazards expected at the onset of the summer monsoon. They also helped the Resident Coordinator's office to assess and understand a range of scientific information on the earthquake and its associated hazards.

The EwF team advised DFID London and Nepal offices directly on the evolving landslide hazard, including an extended briefing and question/answer session on 9 June that was attended by much of the DFID Nepal office. They also compiled maps of co-seismic and post-seismic landslides and made them available on the EwF blog. A direct outcome of this work was a new set of guidelines to minimise exposure to landslides triggered by earthquakes or monsoons, produced by EwF and NSET. These are based on research on the landslides

triggered in 2015 and subsequently, and produce, for the first time, a science-based set of guidelines, expressed in simple language and with simple rules of thumb for where to build (and not build) new houses. Importantly, these guidelines reflect the social, cultural and political context in which decisions are taken at the household and community level, with the potential to inform some of the post-earthquake reconstruction in rural areas.

A key area of continuing work in Nepal, with support from DFID and NERC through the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, is supporting communities at risk of landslides following the 2015 earthquakes. Central to this is understanding how the landslide hazard is evolving over time, the concerns and needs of householders living with this uncertain and evolving risk, and the role and capacity of government stakeholders tasked with mitigating and managing the risks faced. We see this as a unique opportunity to bring together several interlinked strands of research on disaster risk governance, CBDRR and post-disaster response and recovery to inform the ongoing reconstruction.

A further area of impact emerged from a request from the Nepal Risk Reduction Consortium for the EwF team to undertake a review of Nepal's 9 Minimum Characteristics of a Disaster Resilient Community, a strand of CBDRR policy guiding NGO interventions at the sub-national level. Our report highlighted the need for a flexible, locally informed approach to the revision of the Local Disaster Risk Management Planning Guidelines. The National Disaster Reduction Centre of China has also shown interest in the guidelines, which a view to informing their own 'Example Resilient Communities' model. This has been further explored as part of a follow-on IRNHiC project.

China

Quite early in the project, it became clear to us that two profound disconnects exist within Chinese earthquake DRR practice: one between top-down policy and bottom-up implementation, and the other between science and policy. These were clearly articulated by stakeholders at all levels.

The course of the work in China was completely redirected as a result of the EwF Partner Meeting in Kathmandu in April 2015. This was a key experience for the delegates from the PRC, who were able to make links with colleagues from other countries, particularly Nepal. In particular, they were powerfully impressed by NSET's resilience-building efforts, and by the fact that these were based on a thorough understanding of the science, engineering, and societal aspects of risk mitigation. These impressions were reinforced vividly by the devastating earthquake that hit Nepal 10 days after the meeting.

As a result of these experiences, the idea was born of bridging the top-down/bottom-up and science/policy divides through the use of properly calculated earthquake scenarios. This led to a successful proposal to the IRNHiC programme to carry out a full scenario on the city of Weinan (population ~1M, near to Xi'an, pop. ~10M). This scenario, which is based on an aftershock of the 1556 earthquake, is close to completion at the time of writing, and has involved EwF personnel, GeoHazards International, a California-based organization devoted to disaster mitigation, scientists from the Shaanxi and Chinese Earthquake Administrations, and civic leaders at the city and provincial level. The degree of commitment has been remarkable, and the work of Prof Su Guiwu of the CEA in handling the delicate negotiations about foreign involvement in a highly sensitive project has been truly outstanding.

Central Asia

In the geological work, we identified a number of active faults near the major cities of Central Asia, including those responsible for a series of earthquakes, in 1885, 1887, 1889, and 1910, which seriously damaged Almaty and Bishkek. Our collaborators and we produced some of the first modern scientific outputs connected with earthquake hazard in Kazakhstan by carefully documenting these active faults with state-of-the-art techniques. As a result of this work there is now, for the first time, a probabilistic seismic-hazard map for the region that is based on modern earthquake science.

Directly as a result of the Tabriz Statement (see Iran, below), our colleagues in Kazakhstan and Kyrgyzstan convened equivalent meetings in Almaty and Bishkek which also declared a radical new approach to earthquake-risk mitigation. The Almaty meeting, in particular, which involved our EwF partners from Iran, Italy, Germany, Nepal, India, China and Kyrgyzstan, as well as the UK, concluded with a set of resolutions that were endorsed and adopted by the conference and which are recognizably similar to those of the Tabriz statements in Iran. This approach represents a very different view of the problem from that held previously by authorities in Kazakhstan. Scientists from other Central Asia countries are now keen to join the EwF partnership and considerable progress, though on the science side alone, has already been made in Turkmenistan.

Iran, India, Southern Europe

Our Iranian colleagues adroitly employed the authority and respect arising from their participation in the international partnership to strengthen engagement with their civic leaders during the course of the project. A tangible outcome is the Tabriz Statement issued by the Geological Survey of Iran listing the realities of earthquake risk and mitigation in the country, which is remarkable for its good sense and scientific accuracy (see Annex 2). n particular, this statement emphasises the ineffectiveness and danger of any allowed or perceived link between public-safety policy and short-term earthquake prediction, and stresses that individuals, communities, and policy makers must take responsibility for mitigating their own earthquake risks. We have also made considerable progress in revealing and publicizing earthquake hazard, in particular the politically sensitive documentation of a major active fault running through Tehran. Our Iranian colleagues are also now contributing scientific know-how to neighbouring countries, through the EwF partnership.

In India, the EwF team were able to encourage the connection between knowledgeable Indian earthquake scientists and various State Disaster Management Authorities in Jammu & Kashmir, Bihar, and Uttarkhand. We have also run training meetings and workshops (in Jammu and Kolkata) for students from institutes across India. Joint field-based research with Indian partners has helped clarify earthquake hazard in peninsula India, where large destructive earthquakes occur within the thick cold Indian shield (e.g. 1895, Latur, 1997 Jabalpur, 2001 Bhuj).

Before the EwF project began, a tsunami hazard was known to exist in the Eastern Mediterranean, but it was not well characterised – and was mis-attributed to the fault on the subduction interface beneath Crete. Our work, which showed that the hazard is associated not with the subduction interface but with faults within the over-riding Eurasian continent, is published in a comprehensive study detailing the potential impacts along the shores of the Eastern Mediterranean. This work has also fed into new assessments of tsunami hazard on the Makran coast of southern Iran, made during the EwF project. The seismic hazard to countries of the former Yugoslavia and to Albania is less well recognised than that in Italy, Greece, and Turkey, but is nonetheless significant. Scientists from Albania initiated a collaboration with EwF, and we are pursuing other partnerships in the region.

6. Evaluation of Outcomes

The final session at the 2018 Oxford Workshop focused on the three questions underpinning the workshop:

Did the project generate new knowledge?

With over 80 co-authored publications in peer-reviewed journals and innumerable presentations at conferences and seminars, EwF has clearly generated much new knowledge not only on the geology, geophysics and seismology that cause earthquakes, where the faults are, and (very approximately) how frequent and how powerful future earthquakes are likely to be, and the hazard posed by earthquake-triggered landslides, but also on the governance and policy environment for improving resilience and the social and cultural characteristics of communities and what they can do for themselves.

Did the transdisciplinary experiment work?

While the fieldwork in each country evolved in different ways and was often emergent rather than planned, the commitment to engage with all stakeholders throughout has delivered immediately useful impacts including the adoption of guidelines on landslide hazard reduction in Nepal, greater interactions between national and local agencies in China (and the opportunity to test the scenario model), and raised public awareness and changed attitudes towards earthquake resilience (rather than prediction) in Kazakhstan. Furthermore, the emphasis on co-publication and knowledge-sharing through national and international conferences workshops and seminars has built the capacity of national researchers and policymakers to generate and use knowledge in the future, and has strengthened the global network of individuals and organisations committed to improving resilience to intracontinental earthquakes. It is important to point out, however, that even with the network of pre-existing relationships among partners and the shared focus on earthquake resilience, it was not always possible to bridge disciplinary boundaries and achieve a truly transdisciplinary approach. This remains a challenging task.

What more could be done to maximise the benefits?

Activities essential for continued progress include further on-the-ground policy and practice-focused research with local collaborators, a larger and more explicit network and capacity-building element, especially for young researchers, and more research into the reasons why stakeholders behave as they do. There are opportunities to continue the work though other projects (e.g. the IRNHiC projects in China), and strong existing collaborations in all countries may revive if other funding can be obtained.

7. Lessons

The most important lessons that emerged during the Workshop discussions that were felt to apply across the whole EwF project are outlined below.

Impact of UK Science

It is sometimes claimed that researchers play, at best, a minor role in the uptake of scientific knowledge by policymakers. This was not our experience. Scientific research was central to EwF's achievements, for three major reasons. First, the basic knowledge about where the hazards lie is seriously deficient across all of Eurasia, and, in some of the regions, was practically non-existent before the project began. Second, it will take many years to bring the knowledge of hazard distribution up to the necessary levels, and this cannot be achieved without building up in-country scientific capacity. The best way to build that capacity is by training young researchers through joint research programmes, which we have done, as can be seen from the many publications of this project. The third point is one that our partners repeatedly make to us: Their involvement in a first-class international research programme empowers them tremendously in their interactions with their own governments and policy

makers. The transformations of policy resulting from the Tabriz, Almaty, and Bishkek meetings provide examples of this effect.

Working Across Disciplines

During the preparatory phases of this project, the investigators spent a lot of time worrying about what we had been led to expect would be major difficulties in cross-disciplinary work, and invested considerably in activities to strengthen understanding across the team. The most important unifying mechanism was simply to define the problem clearly – in the present case, to reduce deaths in earthquakes in the developing world – then to work together to identify all the tools that could be brought to bear upon it. Another concern, initially, was that any research addressed towards societal needs would necessarily be of lower calibre than would have been produced in "blue-sky" mode. This fear was unfounded; as we describe above, first-class research was central to EwF's key outcomes. EwF researchers are convinced of the merits of NERC/ESRC's initiative in combining research in natural and social science (including its political and governance aspects). Understanding the social, cultural, and political contexts in which earthquakes are experienced was essential for aligning EwF's responses to the questions and needs of householders, governments and the humanitarian and development community.

The International Partnership

It was essential to work in multiple countries. Earthquakes are a global phenomenon, and the full story cannot be understood by concentrating effort in any one region. Countless lessons are learned by comparing one region with another. This is as true of the earthquake science as it is of the social and political aspects of the problems. Importantly, the partnership is as valuable to the members from high-income countries as to those from LMICs. For example, despite the wide contrast in earthquake-science sophistication between countries in the Mediterranean and Asia, it became obvious that they can share, and learn from, each other's experience in their public's perception, mitigation and prioritization of earthquake risk – in which the similarities between countries were often more prominent than might have been expected from their different social contexts. Indeed, for some overseas partners, the realization that they 'were not alone' was a significant comfort and stimulus from the project.

Local Champions

When the project began, we had close associations with key individuals who know how to navigate their local bureaucracies, are internationally-facing, and have a commitment to supporting the careers of their younger colleagues. We had relationships of trust with these people, which had been built over decades of joint research. Without those pre-existing links, it would have been impossible to operate effectively. We met several people who initially expressed a sincere interest in the goals of EwF – which evaporated once it became clear that we were not a source of money, nor of repeated meetings in 5-star hotels, but were expecting to carry out hard work. Many such folk occupy senior positions in institutions, and without our local champions we should never have navigated around them, to find the energetic and committed people with whom the successful work was carried out.

Resources

The project was constrained to lie within a budget of £2.4M. In retrospect, we were considerably over-ambitious in the goals we set ourselves. To maintain a commitment to collaborative scientific research and engagement with civil authorities across multiple countries requires far more personnel than we could deploy with that budget. We owe much of our achievement to additional resources that were applied to the project, including some person-years of unfunded investigator time. For example, some hierarchical societies require heavy involvement from the senior researchers – there is no point in sending a post-doc to talk to a senior bureaucrat even if, in our eyes, she is the most knowledgeable person about the matter in hand.

It is probably no coincidence that, in the science/policy arena, we made most progress in China. This work received additional funding under the IRNH-in-China programme, and also

benefitted hugely from financial and personnel support from Hong Kong Polytechnic University. Such support cannot be looked for in low-income countries.

A genuine commitment to capacity building is expensive. In developing an unsuccessful bid to GCRF, we formed a conservative estimate of the costs of capacity building in an EwF-type project, through collaborative research, scientific networking, and education. This activity alone was estimated at over £3M – more than the total EwF budget. Although considerable capacity building did nevertheless take place within EwF, many opportunities were lost through lack of adequate funding.

Time Scales

EwF grew out of a bold initiative by NERC and ESRC to bring social and natural scientists together to solve a pressing real-world problem. We were initially oblivious to the fundamental differences between this enterprise and a normal research project (which has a goal, a beginning, a work programme, and an end). Because of our strong pre-existing scientific links, we expected (and found) little difficulty in setting up in-country scientific research programmes that achieved good results within the 5-year span of the project. However, progress was slower on the science-into-policy programmes. We have, in each area, identified pathways to increasing resilience and, in many cases, started to travel along them. In retrospect, however, we were over-ambitious in hoping that those pathways could be opened and made fully operational within five years.

Flexibility

The EwF project was an innovative experiment so, inevitably, some aspects of the plan worked better than others, while events and circumstances threw up unexpected opportunities. It was essential to maintain a flexible and adaptive approach throughout the project; this, in turn, required flexibility in budgets and allocation of resources. We were admirably supported in these adaptations by the IRNH advisory team from NERC/ESRC (led by Peter Sammonds) who, by their close engagement with the project, could both support and advise on course changes, and maintain confidence in our accountability.

Legacy

A major aspiration of EwF was to leave a legacy in the form of a well-networked partnership spanning the countries with high earthquake risk. Our partners have taken tentative steps towards collaborating in the way that EwF is promoting. Kyrgyzstan, Iran, and Nepal are trying to form a multinational group to help each other out, while our colleagues in India are trying to form a similar group across the different Indian states. All of them realize that the effectiveness of such initiatives depends on the international network we have fostered and which we are uniquely capable of nurturing. Although there is currently no direct funding for EwF, we and our colleagues are keeping the partnership alive through a number of actions that will continue to be described on the EwF website.

These efforts point up, however, an ethical problem. The outcomes of EwF cannot be measured by the usual standards applied to academic research grants. The project concerns the lives and livelihoods of millions. As it happens, the 5 years of EwF were relatively quiet, but the 2015 Nepal earthquake alone killed 10,000 people, and will push 1M below the poverty line. Earthquakes with worse outcomes will undoubtedly hit the developing world several times per decade for the foreseeable future.

By undertaking a project with an ODA-related agenda we undertook an obligation that extends beyond the lifetime of the project. During the past 5 years, our work has steadily raised the capability of our overseas partners in earthquake science as well as their expectations and ambitions of successful engagement with their civic leaders and public. Our friends now fear we are going to leave them in the lurch. We – and, we suspect, the research councils – were initially blind to this aspect of the project. This enterprise contributes to the UK's `soft power', but unless that contribution is sustained, it will come to be seen as a short-lived and empty gesture, like so many western interventions in the affairs of developing nations.

Annex 1: Organisations involved

UK Partners

- Department of Earth Sciences, University of Cambridge
- Department of Earth Sciences, University of Oxford
- Overseas Development Institute
- Department of Geography, University of Durham
- Department of History, University of Hull
- School of the Built & Natural Environment, University of Northumbria
- British Geological Survey (Hazards Group)
- Institute of Geophysics and Tectonics, University of Leeds

International Partners

- Institute of Geosciences, Energy, Water and Environment, Polytechnic University, Tirana, Albania
- Hong Kong Polytechnic University, Department of Applied Social Sciences
- Institute of Geology, China Earthquake Administration
- Gender Development Solutions, China
- Shaanxi Earthquake Administration, China
- Sun Yat-Sen University, School of Earth Sciences and Geological Engineering, China
- Technical University of Crete and Academy of Athens, Greece
- Technical University of Athens, Greece
- Tata Institute of Social Sciences, India
- Bihar State Disaster Management Authority, India
- Indian Institute of Science Education and Research, Kolkata, India
- Geological Survey of Iran
- Institute for Advanced Studies in Basic Sciences, Zanjan, Iran
- National Cartographic Center, Iran
- Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
- Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
- Kazakhstan National Data Center, Almaty, Kazakhstan
- Yessenov Foundation, Almaty, Kazakhstan
- Institute of Seismology, Academy of Sciences, Kazakhstan
- Kazakhstan Red Crescent Society
- Institute of Seismology, Bishkek, Kyrgistan
- Nepal Risk Reduction Consortium
- National Society for Earthquake Technology - Nepal
- Nepal School of Social Work
- Kandilli Observatory and Earthquake Research Institute, Boğaziçi University, Istanbul, Turkey
- Institute of Seismology & Atmospheric Physics, Academy of Sciences of Turkmenistan

Regional Partners

- Asian Disaster Preparedness Centre
- Cambridge Central Asia Forum
- International Centre for Integrated Mountain Development

Annex 2: Tabriz Statements

The statements below formed the closing statements of a session of Earthquake Hazard and Risk, sponsored by the geological Survey of Iran, at the 32nd National and the 1st International Geosciences Congress in Tabriz, Iran 17-18 February, 2014.

They were influential in assembling also the final resolutions at the Ewf_sponsored conference on Earthquake Science and Hazard in Central Asia, Almaty, Kazakhstan on 7-9 September 2016, see: https://www.odi.org/sites/odi.org.uk/files/resource-documents/11151.pdf

- Nearly all of Iran is vulnerable to earthquakes. A large proportion of the population of Iran is exposed to earthquakes and their associated hazards, such as landslides, particularly in cities.
- Earthquakes have caused, and will cause in the future, enormous loss of life, injury, destruction of property, and economic and social disruption. Such loss, destruction, and disruption in earthquakes can be substantially reduced through the development and implementation of mitigation measures.
- The current state of earthquake science is unable to predict the precise time at which any earthquake will occur. However, with appropriate and sustained research, it is increasingly possible to identify the approximate locations of future earthquakes and to forecast their likely size and character, from which an estimate of the level and nature of the hazard can be made. The risk associated with the hazard can then be reduced by appropriate educational, social, political and engineering action.
- The experience of countries such as Japan, Chile, California and New Zealand shows that this approach, practiced over decades, is effective at increasing resilience to earthquakes and, in particular, at reducing the number of deaths in earthquakes. It is not necessary to predict the precise times of earthquakes to have a dramatic effect in reducing their consequences.
- Realistic assessment of earthquake hazard requires work. In particular, it is necessary to identify active earthquake-generating faults, which may be unknown or hidden. With careful research, their characteristics can be revealed, including their long-term movement rates and the past history of earthquakes on them.
- Instrumentation, monitoring, and data gathering to characterize earthquakes are essential activities to develop better knowledge about earthquake hazard and to assess the risks this hazard poses to communities.
- The vulnerability of buildings, lifelines, public works, as well as industrial and emergency facilities can be considerably reduced through proper earthquake-resistant design and construction practices. Infrastructure that supports electricity, transportation, drinking water, medical assistance, food distribution and other services is vital immediately after a disaster, and a quick return to functionality speeds the economic and cultural recovery of the affected community.
- The experience of several countries shows that appropriate building codes and standards, if observed, can greatly reduce the damage caused by earthquakes. However, the education of the public, including officials, is required for effective implementation and observance of such codes.
- Significant reduction of earthquake risk depends on individuals and organizations in the private sector taking some responsibility for their actions, so they can be more effective. The current capability to transfer scientific knowledge and information to these sectors is inadequate. Improved mechanisms are needed to translate existing information into reasonable and usable specifications, criteria, and practices.
- Severe earthquakes are a worldwide problem. Since damaging earthquakes occur infrequently in any one nation, international cooperation is beneficial for mutual learning from limited experience.
- Earthquakes do not recognize political boundaries. A large earthquake can have devastating effects beyond a country's borders. Regional collaboration and joint scientific projects are therefore crucial for proper understanding of the hazard and reducing risk to societies.

Annex 3: EwF Publications to End-2018

2018

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