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Early warning and early action – an introduction

At the dawn of the 21st century, the devastation and human tragedy wrought by natural hazards once again occupied global headlines. For a few days in February 2000, the international media focused its cameras on Mozambique, with heart-wrenching pictures of helicopters plucking families from rooftops and the miraculous story of baby Rosita, born in a tree. Although the death toll from the Mozambique floods was not large compared with other recent disasters, the press coverage was intense and dramatic rescue footage was captured and broadcast around the world (Christie and Hanlon, 2001).

History seemed ready to repeat itself in 2007 and in 2008, when serious floods again hit Mozambique. Yet the 2007 and 2008 floods hardly registered with the global media; there were no dramatic helicopter rescues and the final death toll was less than 30 in 2007 and six in 2008 (EM-DAT).

Did something change between 2000 and 2008 in Mozambique? The answer is clearly "yes". Mozambique has made excellent progress in linking early warning with early action – the focus of this year's *World Disasters Report*. Instead of waiting for the floods to trap people in trees and necessitate dramatic and expensive helicopter rescues, the authorities have put systems in place to ensure action is taken before the flood or cyclone becomes a major disaster. The improvements lie mostly with the advent of community-centred early warning systems (EWS); they have linked global and national capacity to provide timely warnings of floods and cyclones with early action taken by the at-risk communities themselves. Most importantly, many Mozambican communities now have the skills and knowledge to protect themselves when they are warned of an impending disaster (International Federation, 2007).

Is the Mozambique experience transferable to other potential hazards in other countries? The answer is a qualified "yes". Aspects of community-centred EWS can be applied in other contexts, but it is equally clear that there is no 'one size fits all' early warning system for all hazards in all countries. A number of other countries have excellent flood and cyclone EWS – such as Bangladesh and Cuba – yet each system differs significantly from others. Chapter 2 of this report explores community-centred early warning in more detail, highlighting the need for locally based solutions.

Can further improvements be made to well-functioning flood and cyclone early warning systems such as Mozambique's? While many Mozambican communities now receive warnings and have the capacity to evacuate before a major flood, or take shelter before a cyclone instead of waiting to be rescued after the event, even earlier action is

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Photo opposite page: In China, Wang Huai Min sits on a makeshift raft that he uses to visit his submerged house. He had no time to salvage any of his belongings and now lives on a dyke with his family of six.

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needed. Poorly constructed houses are still destroyed, livelihoods are set back as crops and livestock are lost, the incidence of malaria and other diseases increases after flood events. Early action means reducing vulnerability through risk reduction activities, such as improving building codes and better land-use planning, enhancing rural banking systems so savings are kept in banks rather than in the form of goods and livestock, clearing drainage canals, stockpiling medicines and mosquito nets. Chapter 3 examines ways to bridge timescales and promote early action.

Finally, does the Mozambique experience mean that early warning systems have evolved sufficiently to avoid massive casualties from natural hazards? Unfortunately, the answer to this question is a categorical "no", as demonstrated by the 138,000 deaths in 2008 from Cyclone Nargis in Myanmar. Cyclone Nargis was a highly unusual event, affecting a part of Myanmar unaccustomed to cyclones. Myanmar, like Mozambique, faces a multitude of hydro-meteorological risks and these are likely to grow more extreme given the realities of global climate change. (In addition to anomalies provoked by climate change, extreme natural events like earthquakes will continue to occur with little or no warning.) Highly unusual events will increase, cyclones and floods will suddenly affect new areas, more regions will experience extreme heat or cold. Chapter 4 examines how global climate change offers challenges and opportunities to early warning systems and for early action.

The fundamental goal of early warning is early and balanced action. Any actions taken before a disaster strikes – whether a few minutes before the event (moving to higher ground during a storm) or a few months beforehand (preparing contingency plans, building stockpiles) or years before (planting trees on hillsides, strengthening building codes) – can help prepare for, mitigate or prevent the hazard from becoming a disaster.

This chapter will examine the progress and success in efforts to develop early warning systems over recent decades, as well as highlighting some of the many remaining challenges at the global, regional and national levels. It will trace the evolution in EWS and describe current thinking about the most effective ways that early warning can lead to earlier action.

The evolution in early warning

As the death toll from Cyclone Nargis in Myanmar in 2008 rose above 130,000, people repeated the same questions that were asked after the Indian Ocean tsunami claimed 250,000 lives in 2004. Why were no systems in place to alert coastal residents of the incoming threats? Could nothing have prevented the loss of so many lives?

Global attention caused by these mega-disasters has given additional impetus to the ongoing efforts to improve early warning systems for natural hazards, which had begun gaining momentum towards the end of the 20th century (see timeline in UNISDR, 2006a). The 1990s were declared the International Decade for Natural Disaster Reduction and the first global early warning conference was held in 1998 in Potsdam (Germany). Early warning practitioners had begun to examine systematically early warning systems to identify their strengths and weaknesses.

Not that the concept of early warning for emergencies is new. It is centuries old. The ancient Chinese used smoke signals from the top of the Great Wall to warn of impending attacks by enemy troops. For hundreds of years, the health sectors in many countries have had warning systems to provide alerts on the outbreak of contagious diseases, and they continue to do so. Modern-day food security practitioners still refer to the sophisticated price monitoring systems established in the Indian Famine Codes in the 1880s, which not only provided early warning but triggered response to potential famines.

Contemporary early warning systems emerged in the 1970s and 1980s, as a response to drought-induced famines in the Sahel. Since droughts, food insecurity and, ultimately, famine evolve very slowly, governments and donors postulated that by tracking certain indicators, such as malnutrition, market prices or rainfall levels, it would be possible to anticipate future food insecurity and intervene before people starved to death. Today, the number of deaths due to drought-induced famine has been reduced dramatically. Early warning systems for food insecurity continue to evolve and improve, although there remains a large gap between warnings and response, especially the capacity and capability to provide longer-term response to address vulnerability and the root causes of risk, as discussed in Chapter 5.

Other hazard-specific early warning systems have emerged, especially in developed countries and especially for frequent hazards. Tornado warning systems are well developed in the United States, for example; many countries have established flood early warning systems for major river basins; cyclone warning systems exist and represent excellent examples of international cooperation. Early warning systems for volcanoes exist in most regions or countries where there are active volcanoes (see Box 1.1). Interestingly, the tsunami early warning system for the Pacific Ocean has been operational for more than 40 years yet such a system was absent in the Indian Ocean in 2004 due to the infrequency of tsunamis in this region.

Early warning is a system, not a technology

The three global early warning conferences (1998, 2003 and 2006) catalysed efforts to examine what was working and what was not working in early warning. The 2005 World Conference on Disaster Reduction in Kobe, Japan followed by the third early warning conference in Bonn, Germany in 2006, led to notable progress in linking early warning to early action and risk reduction. From these processes emerged a

Box 1.1 Early warning systems for volcanoes

Early warning systems for volcanoes have been adopted in many regions where volcanoes are active. They work as a coordination and communication tool between scientists and other stakeholders to help minimize the economic and social impact of volcanic activity. Individual volcano early warning systems (VEWS) vary considerably due to a number of factors including the ability to monitor and forecast volcano hazards, management of volcano observatories and broader social, political and economic issues. The organizations that coordinate VEWS are predominantly the volcano observatory if there is one (it may be part of a local university), emergency managers/civil defence or, in some cases, the local government, but the coordination varies depending upon the country and its disaster management policy. VEWS can operate from the local level of an individual volcano, through to regional, national and international levels (particularly for the aviation sector). The United Nations has provided a number of generic EWS guidelines that some governments may or may not adhere to.

Volcanic activity presents a complex problem for volcanologists and emergency managers; they have to forecast and manage a diverse range of hazards that may occur, sometimes without warning, when volcanoes are active or dormant. Volcanoes can produce a wide range of hazards: from fall processes (ash and ballistics), to flowage processes (pyroclastic flows, surges, lateral blasts, debris flows/lahars, floods and lava flows) and volcanic gases, earthquakes and tsunamis. Approximately 10 per cent of the world's population live within close proximity to one of the 1,511 known active volcanoes, and yet populations living some 100 kilometres away from volcanoes and unaware of volcanic activity can be devastated by lahars (type of mudflow or landslide composed of pyroclastic material flowing down from a volcano) or ash. Therefore the vulnerability of a population living near a volcano depends heavily on its geographical location, infrastructure, the hazards' characteristics and also weather conditions at the time of activity.

Unlike other hazard types, some volcanic hazard processes can occur very rapidly; for example, pyroclastic flows travel at more than 80 kilometres/hour, rendering the ability to provide a warning futile. Forecasting, therefore, plays an important role in volcano hazard management. Scientists work to identify, map, date and develop a volcano's history and monitor its activity to establish a baseline that can be used to detect abnormal behaviour. VEWS have been developed to provide warnings to populations at risk from volcanic hazards to allow them to seek safety, both locally and regionally. At the very core of VEWS is decision-making, but equally important is the communication, dissemination and understanding of a decision and what it means. This makes VEWS a key interface between scientists, civil authorities, the public and other stakeholders.

Ideally, emergency managers require information relating to: when and where the volcano will erupt; the magnitude, style and duration of the eruption; likely hazards and expected location; and the effect of volcano hazards at the local, regional and global levels. In contrast to other hazard types such as hurricanes or landslides, these questions are difficult to answer due to a number of key aspects (see Table 1).

Therefore managing volcanic crises requires careful consideration and understanding of how to take action in the context of extreme uncertainty, from both scientific and social standpoints. To do this successfully a VEWS should

Table 1 The complexities of volcanic hazard information

Scientifically	■ Volcanologists and related scientists are still developing theories to understand the origin, processes and eruptive behaviour of volcanoes and the numerous associated hazards.
	■ This makes predicting and forecasting volcanic activity and hazards extremely complicated.
Socially	■ Volcano hazards generally occur on a larger time frame than political terms or human generations and therefore are not normally a priority.
	■ This generally results in limited funding and resources for monitoring volcanoes and conducting research on their past activity, and limited volcano hazard awareness.
Institutionally	■ Increasing levels of bureaucracy and contending stakeholders mean that decisions can be complex and protracted.
	■ The wide-ranging impact of volcano hazards tends to involve many institutions and it is difficult to maintain communication both within each institution involved and externally.

be fully integrated so that it covers everything from monitoring and detection, to analysis and interpretation of the data, to communication and generating an effective response. This requires planning, cooperation, the running of drills, education, and discussion and communication between all stakeholders so that during a crisis effective decisions can be made quickly. The ability to develop, provide and maintain a successful VEWS is built around five key components listed in Figure 1 (see below).

While the VEWS model may appear to be linear, there is ongoing interaction between the five components and the different knowledge groups within the system. The five components have functions before, during and after a crisis;

Figure 1

A model for a successful volcano early warning system

1. Understanding and forecasting volcano hazards	2. Volcano scientists management	3. Volcano crisis management	4. Response	5. Broader economic, political and social issues
Volcano style	Hazard mitigation and mapping	Crisis planning	Education	Communication
Eruptive history	Monitoring	Decision-making	Ability to obtain warning	Education
Period of quiescence	Research	Media management	Aware of what to do	Funding
Tectonic location	Outreach/education	Communication with the public and other authorities		Technology
Volcanic hazards	Alert notification system and crisis planning			Cultural environment
	Institutional dynamics			Coordination of institutional and public relationships

neglect of any one of these through the cycle may cause a VEWS to fail. What is most unusual about a VEWS is that in any one crisis the dynamics are likely to be unique, and therefore it seems no real 'rule of thumb' can be applied to managing a crisis, only guidelines of best practice.

History has shown that if the management of a volcano crisis is not successful, volcano disasters can cause significant loss of life, socio-economic impact and damage to the environment, thus there is a demand and benefit to mitigating against volcano hazards. Conversely, given the existing advantages of living within a volcanic area (fertile and mineral-rich volcanic soils, geothermal heat, hot springs, tourism and unique scenery), there can be a perception or reality that too much money is being spent on a precautionary approach for a hazard that is unlikely to occur within the population's lifetime. The result is divergent attitudes to risk in different environments. A balance needs to be established, although often there are not enough resources to provide basic monitoring and understanding of many volcanoes to develop a mutual understanding of acceptable risk by the scientists and public.

The lack of such understanding, the failure to comprehend the risks involved and the procedures that manage volcano crises has led to a number of unnecessary disasters. In 1985, the Nevado del Ruiz volcano in Colombia generated a lahar that killed more than 23,000 people (Voight, 1990). Despite the scientists' and authorities' awareness of the hazard, it was human misjudgement, indecision and bureaucratic short-sightedness that led to this disaster. Other examples of historical disasters have been caused by political interference (the 1902 eruption of Mont Pelée that destroyed Saint-Pierre, Martinique killing 30,000 people), miscommunications between scientists and the media (a conflict in the interpretation of volcanic activity at Guadeloupe during 1976 led to the important lesson of providing one clear and consistent message from scientists to users) (Fiske,1984) and interactions and relations between scientists and authorities (this generated problems in communicating the risk level of the local population with the government and public at Montserrat in 1995 that are still ongoing) (Aspinall et al., 2002). In Goma (in the eastern part of the Democratic Republic of the Congo), the local Red Cross is actively working with local authorities and the Goma volcano laboratory to disseminate early warning information to local populations. This collaboration started shortly after the eruption of the Nyiragongo volcano in 2002 in which many lives were lost and properties destroyed. A database for volunteers has been set up, and training sessions for volunteers on the prevention of volcano risks organized.

The recognition that volcanologists have a moral obligation to communicate their knowledge effectively for the benefit of society has led to some successful VEWS. In Japan, during Mount Unzen's violent eruptive activity from 1990 to 1995, officials developed a VEWS which resulted in the effective evacuation of 12,000 residents in 1991. Consequently a number of large structures to minimize destruction from lahars by trapping sediment and channelling the flows were developed, which was extremely costly but enabled rehabilitation.

Also in 1991, the eruption of Mount Pinatubo in the Philippines demonstrated the importance of education (Newhall and Punongbayan, 1997). Using a video on *Reducing Volcanic Risk* filmed by the late Maurice and Katia Kraft, the scientists helped the government understand the extent of devastation that Mount Pinatubo could cause, and generated the political will for the safe evacuation of more than 60,000 vulnerable people.

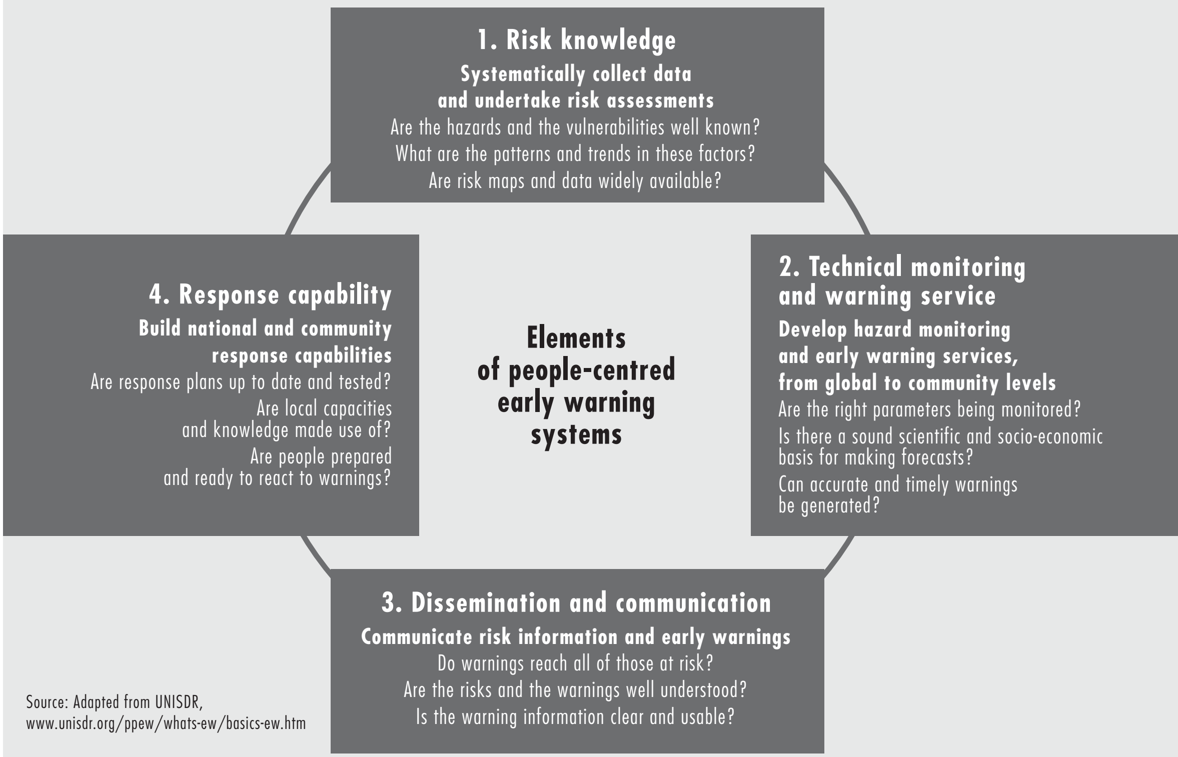
Volcano-related disasters to date imply that the effectiveness of VEWS has been, and continues to be, hindered by institutional weaknesses in procedures and infrastructures, poor integration and sharing of knowledge between scientists and stakeholders, and effective communication without the scientific understanding or level of warning technology available. ■

new consensus: early warning is not only the production of technically accurate warnings but also a system that requires an understanding of risk and a link between producers and consumers of warning information, with the ultimate goal of triggering action to prevent or mitigate a disaster.

This analysis has broken early warning systems into four separate but interlinked elements as shown in Figure 1.1 below:

- risk knowledge
- technical monitoring and warning service
- dissemination and communication of warnings
- response capability and preparedness to act (by authorities and by those at risk)

Figure 1.1
Elements of early warning



Source: Adapted from UNISDR, www.unisdr.org/ppew/whats-ew/basics-ew.htm

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In recent decades, much effort has gone into the second component of early warning systems – developing the technical capacity to detect and produce good warnings. While this component has seen the most obvious improvements, recent disasters clearly show that the production of technically sound warnings can be nearly meaningless if not preceded by an assessment of risk or followed by clear dissemination and appropriate response capacity. As succinctly stated in a report on the Sri Lanka early warning system, "Public warning is a system, not a technology" (LIRNEasia, 2005). Excessive focus on technological solutions without balancing the other components is not only expensive but it can create a false sense of security.

Some effort has gone into building risk knowledge, in terms of both scientific assessment of return periods and frequencies of various disasters, and socio-economic assessment of human vulnerability to various risks. However, much of the effort to build risk knowledge has been based on analysis of historical patterns such as past tracks of cyclones or river levels. Climate change means historical analysis of risk may be a less reliable guide to future risks so renewed efforts must be made to understand ever-changing and less predictable risks (see Chapter 4).

The *Global Survey of Early Warning Systems* (United Nations, 2006) clearly stated the fundamental problem with the current status of early warning: "Failure in any one of these elements can mean failure of the whole early warning system."

The elements of early warning systems most likely to fail are the last two – dissemination and communications of warning, and response capability and preparedness to act. A people-centred approach is especially essential for these two elements, one that focuses not only on the science and technology behind the warnings, but also on the social and psychological aspects of early warning and early action and on activities to build a culture of prevention, rather than a culture of short-term response (see Chapter 2 for more on the community-based approach).

The devastation caused by Cyclone Nargis in Myanmar in 2008 was not due to a technical failure in the early warning service – warnings were provided by the Myanmar Meteorological Service – but to a failure in the other elements of effective early warning, especially communications and preparedness to act.

However, the Cyclone Nargis case should not be oversimplified but used to illustrate the enormous challenges faced by efforts to create early warning systems. Whether due to climate change or not, Cyclone Nargis was highly unusual. It did not follow 'normal' cyclone tracks, but hit from the west and forced water up the Irrawaddy Delta, flooding the vast low-lying delta very quickly. And even if the warnings had reached the delta's residents, it was such an unusual event that many people would not have believed or been prepared to act on the warnings. Their capacity to evacuate the area would have been severely limited by poor roads and infrastructure. How

Photo opposite page: A group of Masai women in Kenya listen to radio broadcasts on a Freeplay Lifeline radio. Wind-up and solar-powered radios can ensure disaster warnings reach the last mile – the poorest, most vulnerable and most remote communities.

can a poor country like Myanmar fully prepare for anomalous events that may not recur for decades or even centuries?

Working towards a multi-hazard approach

One solution to the dilemma highlighted by the Myanmar disaster may be in the adoption of a multi-hazard approach to early warning, especially for relatively infrequent events or for regions vulnerable to many different types of hazards. This approach does not advocate the creation of one 'mega' early warning system for all hazards, but it focuses on the logical linkages such as shared observation systems for certain hazards and multi-hazard public education campaigns.

The multi-hazard approach can be adopted at global, regional, national and local levels. The city of Shanghai, for example, has pioneered efforts to establish a multi-hazard approach. One of the most densely populated cities in the world, Shanghai faces unique challenges in providing early warning of hazards to its 17 million residents. The city experiences many natural hazards including typhoons, tornados, strong winds and floods and also faces risks of chemical spills, nuclear accidents and public health emergencies. Building on priorities articulated in the Hyogo Framework for Action, Shanghai has created an integrated multi-hazard early warning system.

This system has integrated a 'top-down' approach with unified policies, data collection systems and multi-agency command structures with a 'bottom-up' approach that ensures the community is aware of the risks, understands appropriate responses and can channel information upward to emergency response authorities as well as receive information transmitted from authorities (Xu, 2006).

While the Shanghai system relies heavily on GIS (geographic information systems) and other state-of-the-art technologies, less developed mega-cities can learn from its approach. Its grid-based system divides the city into manageable units for preparedness and response.

Another advantage of the multi-hazard approach is that by pooling resources and hazards, the system will be triggered more often. Early warning systems improve only through use and practice. It has been demonstrated repeatedly that the components of preparedness systems erode over time, so it is extremely difficult to maintain EWS for disasters that may occur very infrequently (Burton, Kates and White, 1993; UNISDR and German Committee for Disaster Reduction, 2006).

It is important to emphasize that multi-hazard systems do not replace single hazard systems, especially for frequently occurring hazards. Different technical agencies will be involved (for example, hydrological departments for floods, geological departments for earthquakes, health departments for epidemics), lead times will be very different (hours for floods, weeks for epidemics) and the appropriate response will be unique (evacuate for floods, improve sanitation for epidemics). A multi-hazard approach would not force these processes into one mega-system but would identify logical linkages and data-sharing possibilities, to remove any duplication and ensure synergies.

As the number and magnitude of natural hazards are projected to continue to rise, and the number of people living in areas vulnerable to these hazards increases, it will be impossible to invest in separate early warning systems for each potential hazard, for every area at risk. The cost–benefit of EWS has not been studied comprehensively, especially in developing countries, but it is clear that certain hazards occur very infrequently – including tsunamis in the Indian Ocean. Creating separate early warning systems for each potential hazard would be prohibitively expensive.

Early warning as a global priority

Because hazards do not recognize national boundaries, a global network of organizations supports national and local efforts to provide effective early warning. While many United Nations (UN) agencies, regional bodies and non-governmental organizations contribute to this global network, major roles are played by the World Meteorological Organization (WMO) with its data collection and sharing networks including the Global Observing System, Global Telecommunications System and global data processing and forecasting system, and the UN International Strategy for Disaster Reduction (UNISDR) which promotes policy, strategic and programmatic work on disaster risk reduction.

Notable single hazard systems include the Japanese government and WMO's efforts to monitor floods globally, with the Global Flood Alert System, under the International Flood Network. The UN's Food and Agriculture Organization leads efforts to track food insecurity through the Global Information and Early Warning System, the World Health Organization (WHO) leads global mechanisms to issue health-sector early warnings and major coordination efforts are under way to improve tsunami warnings for various oceans, under the Intergovernmental Coordination Group operating through the UN's Educational, Scientific and Cultural Organization (UNESCO).

The global tropical cyclone warning system is one of the best examples of international, regional and national collaboration in technical monitoring and warning. The WMO's global operational network enables continuous observation, data exchange and regional forecasting.

Six regional specialized meteorological centres provide forecasts, alerts and bulletins to national meteorological services in all countries at risk with lead times of 24–72 hours. The national services then issue warnings to governments, the media and the general public according to national protocols. Historical risk areas are well established (although historical patterns are becoming a less reliable predictor, as demonstrated in the case of Myanmar) and five regional tropical cyclone committees work continuously to enhance forecasting skills.

Enhancing early warning systems was a key priority of the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities (HFA), which was the major outcome of the World Conference on Disaster Reduction in Kobe, Japan, in January 2005. The HFA emphasized the importance of preventing loss of lives and livelihoods and reducing potential economic impacts rather than merely reacting to disaster occurrences. It also advocated a multi-hazard approach to improve the effectiveness of risk reduction activities.

The framework marked the beginning of a new era for disaster risk management. Among its five priorities, it called for disaster risk reduction to be made a national and local priority with a strong institutional basis for implementation, and stressed the importance of identifying, assessing and monitoring risks and enhancing early warning.

The HFA articulated the need for governments, regional and international organizations and the development sector to integrate disaster risk reduction into their sustainable policy, planning and programming at all levels. It stressed that early warning systems contribute to the sustainability of development.

Early warning as a national priority

The Hyogo Framework for Action placed the primary responsibility for implementation and follow-up on national governments. Ensuring its citizens' safety is a primary responsibility of government, and national leadership and ownership are keys to effective early warning and early action. Of course, the state must forge partnerships with local leaders, civil society, the private sector, the scientific and academic communities and the media to implement effective early warning systems (see Box 1.2). The state also must ensure regional organizations complement their national efforts to build effective EWS and disaster reduction strategies.

Box 1.2 Technology and volunteers support an early warning system in Jamaica

The Rio Cobre Gorge forms part of the major transportation link between Kingston, the capital of Jamaica, and the north coast of the island, which is the major tourist centre. This is a critical route because tourism is the primary foreign exchange earner for the country. However, the main road through the gorge runs parallel to the Rio Cobre River for several kilometres and is eight metres above the river bed. The river, therefore, floods the road quite frequently. Reports from 1886 indicated that during the passage of a hurricane, the river rose 7.62 metres above the river bed.

Prompted by the frequent flooding of the gorge and the risk posed to commuters and tourists, in the early 1980s the government installed an automatic early warning system. The system is operated jointly by the fire service, the Office of Disaster Preparedness and Emergency Management, the police and the Underground Water Authority (UWA).

It is designed to operate on a real-time basis, i.e., to transmit information on the river's current water levels on a continuous basis to the UWA. Any increase in the flow of the river would be monitored and a warning issued if the water attained a critical level. This transmission of real-time data would enable the relevant authorities to close the gorge and divert traffic to alternate routes before the area was flooded.

However the problem of commuters being trapped in the gorge by rising waters continued to be a periodic problem, despite the installation and operation of the early warning system. In early November 2008, 150 people had to be rescued by the fire service. This flood highlighted the need for public education with regard to the gorge and intensified efforts to upgrade the warning system.

Although designed to operate automatically using a wide array of rain gauges located within the surrounding watershed, the EWS had experienced operational difficulties in the transmission of data from remote sites. In order to circumvent this problem, a combined manual and automatic system was devised. Under this new system, volunteers in the neighbouring communities were recruited by the UWA and trained to read the river gauges. These volunteers are always ready to move to their assigned location when notified to do so by the authority. Manual readings are carried out and the UWA is contacted once the river has attained a height of six metres. This provides a window of opportunity for the necessary protective measures to be implemented before the road becomes impassable when the river reaches a height of eight metres.

Efforts are also under way to improve the system by incorporating active and passive technological measures. These include the installation of electronic signs and sirens to alert motorists of the road closure, gates to deny access through the gorge once a critical water level has been reached and cameras to monitor the movement of traffic.

At the same time as the upgrading of the system, a public education exercise will explain how the system operates and what actions should be taken once a warning has been issued. Warnings will be issued via radio and TV. The use of text messages via cell phones and the internet is being investigated. ■

The HFA follow-up documents, *Words into Action: A Guide for Implementing the Hyogo Framework* and *Developing Early Warning Systems: A Checklist* (UNISDR, 2007 and 2006b), fully articulate the steps national governments must complete to reduce risk and build resilience. If governments make a fundamental commitment to supporting all elements of early warning systems, they will build appropriate policies, linkages and programmes to reduce risk and enhance sustainable development through building safety and resilience.

Early warning as a local priority

Local-level involvement must start with the first element – building risk knowledge. Hazard assessment and risk mapping can help bridge the gap between scientific and local knowledge. In many societies, people overestimate the risk from low-frequency events and underestimate the risk from smaller yet more common events. While general preparedness for catastrophic low-frequency events should be included in a multi-hazard approach, it is important for people to be able to compare risks from different threats and to build up local databases/baselines to better monitor and measure trends, impacts and cost-effectiveness.

Local knowledge can more effectively be built into the second phase – the technical warning service. In the past, local knowledge about early warning signs has been largely dismissed as unscientific, but it is increasingly clear that such knowledge can complement technical warnings. For example, in Mozambique, downstream communities watch the colour of the river water and the size and type of debris floating down to judge the magnitude of a potential flood. Communities monitor many other warning signs, especially animal behaviour (Howell, 2003). Instead of dismissing this local knowledge, it should be studied and integrated into warning systems as appropriate.

In slow-onset disasters such as drought leading to food insecurity and famine, local knowledge is essential. In hydro-meteorological terms, a serious drought may exist but its potential to result in food insecurity or famine is highly dependent on dynamic local cultural and socio-economic trends. For example, the availability of wage labour and the functioning of local food markets can allow households to shift resources into the labour market and withstand a severe drought. If cultural mores require wealthier families to employ poorer households in times of drought, the food security effects of a major drought may be minimal. Conversely, the collapse of labour or food markets, or changes in cultural traditions, can result in drought-induced food insecurity.

Local authorities and communities clearly have a major role to play in the communication and dissemination of warnings. Not only can they assist in the actual transmission of the messages, such as volunteers going from house to house or spreading warnings via local radio broadcasts, but they can also feed information back to the warning providers about how they understand the warnings and how they might be made more actionable or comprehensible.

Finally, local actors must be prepared to respond to the warnings. They must feel knowledgeable about the appropriate actions to take for different sorts of warnings. They must believe that by taking the prescribed actions, they will protect their lives or livelihoods. In some situations, authorities may have to force communities to respond, for example mandatory evacuations, but these can breed resentment if not based on prior understanding. Community-based early warning systems are explored further in Chapter 2.

Linking early warning with early action: the challenges remaining

The fundamental goal of early warning is to prevent human, social and economic losses through action taken before, during and after a disaster strikes. Collaboration from the international to the local level, and building on synergies through a multi-hazard approach, can contribute to early action. This section highlights the major challenges remaining in each of the four elements of early warning systems: risk knowledge, technical warning, communication and dissemination, and response capability.

Major challenges in risk knowledge

There has been an increasing focus on risk perception, i.e., understanding disaster risk through risk assessments, risk analysis and risk mapping, but much of this has been traditionally based on a scientific analysis of the historical frequency, return periods and magnitude of hazards, modelling potential impact on critical infrastructure and calculating the number of people potentially affected based on population densities and demographic characteristics. While this scientific analysis is necessary, a thorough understanding of risk requires an additional, people-centred perspective. Although some efforts have been made to assess vulnerability, which is defined by UNISDR as "the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (UNISDR, 2004), these factors are much more dynamic and difficult to measure than the hazards themselves (see Chapter 2).

Another challenge in acquiring risk knowledge is the very nature of risk. Risk is the interaction between hazard conditions and vulnerability conditions, which means it is an ever-changing process. Climate change and environmental degradation may cause the frequency, intensity and location of hazards to change, while urbanization, poverty, population growth, and disease continuously alter the nature of vulnerability. Risk knowledge should not be seen as a one-time effort to produce expensive and detailed risk maps, but a continual process to understand the evolving nature of both hazards and vulnerabilities.

Lessons can be learned from the health sector, which has grown increasingly sophisticated in understanding risk – not only from a scientific perspective but also from a sociological perspective. The 2002 *World Health Report,* dedicated to the question of risk, stated: "It has been argued that concepts of risk are actually embedded within societies and their cultures, which largely determines how individuals perceive risk and the autonomy they may have to correct them" (WHO, 2002).

People accept a degree of risk, depending on their perspectives. Many people choose to live in flood plains or along riverbanks where the soil is fertile. People choose to build houses along the coast, even when the risk of cyclones is clear. While they face a high risk of floods or cyclones, the fertility of the soil and the convenient or attractive location offers the potential for high returns. Community involvement in risk mapping and risk analysis adds a necessary perspective to scientific understanding. Enhancing vulnerability assessments with understanding of risk perception as well as capacity/coping ability will enhance early warning efforts.

Ultimately, the number of potential risks in the world is limitless. While dramatic mega-events like the Indian Ocean tsunami garner intense international attention, it is necessary to prioritize those risks with the greatest potential negative impact rather than focus on highly dramatic, but very rare, events. The multi-hazard approach can help build systems for less frequent events.

Major challenges in technical warning services

Although technical warning and monitoring have been the main focus of the development of early warning systems, major gaps remain – especially in the poorest countries. While early warning is a national responsibility, many countries still lack the capacity (financial and human resources, organizational, policy) to implement effective multi-hazard EWS. Further gaps exist in drawing in community-level knowledge and data into systems. Community involvement can include collection of 'hard' data

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such as river levels and rainfall quantities as well as participation in scientific inquiry into the veracity of traditional early warning signals. Some efforts to study indigenous warning signs have been carried out (Howell 2003; RAIPON and UNEP 2006), but much more rigorous scientific analysis is required.

Global efforts spearheaded by the UNISDR system aim to ensure better use of existing monitoring technologies, promote a more multi-hazard approach and enhance inter-agency, regional and international collaboration and sharing. One notable effort is the Global Earth Observation System of Systems initiated by the Group on Earth Observation, which intends to build on existing systems and new initiatives to create timely, accurate and inter-operable data on all aspects of the earth, for use in early warning, risk reduction and other endeavours.

The accuracy of warnings must be improved to avoid false alarms. As new warning systems become operational, there is a risk that false alarms will breed complacency. The 'cry wolf' phenomenon has been demonstrated to be accurate – nearly 50 per cent of respondents said they would be less attentive to future warnings after a predicted earthquake failed to materialize (Atwood and Major, 1998). Some 75 per cent of all tsunami warnings in the Pacific Ocean are false alarms, which makes it very difficult to maintain the credibility of the warning systems (Samarajiva and Waidyanatha, 2007). Given the rise in information and communication technologies (ICT) and the difficulty in ensuring that only one, authoritative voice issues warnings, the risk of false alarms is increasing.

Many technical monitoring systems, whether global or national, continue to have a top-down, scientific bias. Warnings based on remotely sensed data or national modelling can miss important dynamics existing at the local level. A major challenge for all technical warning systems is how to build community-level early warning indicators and indigenous knowledge into the system. Early warning systems for slow-onset disasters such as droughts will not be accurate if they ignore community-level indicators. Even for rapid-onset disasters, local indicators can be important elements of the system if properly understood and integrated (see Chapter 2).

Finally, despite all of the progress made in creating fully operational warning services, gaps still remain. After the 2004 Indian Ocean tsunami, observers pointed out that the Mediterranean region is actually more vulnerable to tsunamis than the Indian Ocean, with 10 per cent of all tsunamis occurring there – yet there is no operational early warning system. With 140 million people living in coastal areas, large numbers of tourists and high population density in parts of the Mediterranean, a major tsunami could have devastating consequences. Efforts are under way to quickly establish the technical portions of a tsunami warning systems, but overall progress has been slow and public outreach has been limited (UNESCO, 2008; Greek Ministry of Foreign Affairs, 2008).

Major challenges in dissemination and communication of warnings

Why do messages fail to reach their intended recipient? In most cases, warnings need to be transmitted from a national (or sometimes international) technical agency through multiple receivers before they reach the vulnerable population. Any message that passes through many hands before reaching the ultimate target runs risks of delay or distortion. In the case of a hydro-meteorological threat, the initial warning may be produced by the meteorological department and passed to the disaster management office. It may then be transmitted to other political structures, or to local disaster management offices or local government structures. In many cases, it may be disseminated via the national broadcast media (radio, TV, newspapers) or local broadcasters. It may be channelled through social structures or community-based networks. While many different combinations of channels can work depending on local conditions, each requires close coordination between all agencies involved and a clear understanding of roles and responsibilities.

Even with well-coordinated structures, dissemination to remote areas is still difficult in many places and requires a combination of technological and non-technological solutions. There is no 'one size fits all' solution. For example, the Bangladesh Red Crescent Society's volunteer networks are equipped with megaphones that are vital to the dissemination of warnings in Bangladesh, but such a system does not work in other communities with smaller populations, lower population density and other cultural barriers. There is a need to focus more on 'last mile communication' to ensure warnings reach the final target – the community or individual threatened by a hazard.

Studies have been carried out in Sri Lanka to evaluate the effectiveness of various ICT approaches, including satellite radio and SMS (short message service) sent via cell phones (LIRNEasia, 2008). Even proponents of SMS-based dissemination view it as complementary to other warning channels due to limited cell phone penetration among the most vulnerable, language limitations with SMS, potential damage to cell phone networks during disasters, network congestion and suchlike. The traditional broadcast media remains the most widely used channel globally to disseminate warnings, but the effectiveness of this channel can be compromised if the most vulnerable populations lack access to TVs or radios (see Box 1.3).

It should be noted that early warning communication flows for certain slow-onset disasters, especially food insecurity or famine as well as some diseases, is reversed. Communities suffering from food insecurity or disease outbreaks normally know about the impending disaster before the authorities. Early warning systems for slow-onset disasters must be locally based and controlled, or at least there must be close coordination between national and local systems, to ensure early detection and early response. While populations may have no idea a cyclone or tsunami is coming their

Box 1.3 Radio reaches the most vulnerable people

In many developing countries, traditional broadcast radio remains the most widely used channel for disseminating disaster warnings. Warning messages that are broadcast on radio can quickly reach isolated rural communities where no other form of communication is available.

However, in the poorest communities, even radio ownership is rare. A radio may often be the first 'luxury' good procured by a household, yet the need to purchase disposable batteries means that regular radio use is expensive.

Wind-up and solar-powered radios eliminate the need for batteries or electricity and can provide the poorest households with reliable access to disaster warnings and other lifesaving information. The Freeplay Lifeline radio is both wind-up and solar-powered, and was specifically engineered for conditions in the developing world; it can withstand dust, water and harsh temperatures. These radios can ensure dependable and free access to information broadcast over AM, FM or shortwave frequencies.

The Mozambique Red Cross Society has integrated Freeplay Lifeline radios into its cyclone and flood early warning activities (International Federation, 2007), and the radios have been credited with dramatically improving the country's ability to prevent a repeat of the devastation caused by the 2000 flood and cyclone disaster. A disaster preparedness volunteer is charged with guarding the radio on behalf of the community and listening to broadcasts. When a warning is sounded, the activist alerts village leaders and a pre-planned response is launched. Freeplay Lifeline radios have also been used in Red Cross hurricane preparedness activities in Haiti, as well as in efforts to bring weather information to communities via radio and internet technology through RANET projects in Niger, Kenya, Uganda and other countries.

For 'last mile' warnings to truly reach the poorest and most vulnerable parts of the world, maximizing the use of readily available, low-cost, low-tech solutions such as broadcast radio is essential. ■

way, they know when crops have failed and children show signs of malnutrition or disease, so they must have a significant voice in the early warning systems.

Other reasons for the failure of dissemination and communication of warnings include:

- *Tourism.* While permanent residents can be educated about risks and know where to listen for warnings, visitors are highly vulnerable. Many places with a high number of seasonal visitors, such as in the hurricane-prone Caribbean, tsunami-threatened Mediterranean or many earthquake zones, pose special problems for the dissemination and communication of warnings (see Box 1.4).
- *Trust.* If there has been a breakdown in trust of the messengers, communication can fail. In areas of civil strife, residents may lack trust in authorities or the media. Civil and religious organizations can be vital actors in these cases.
- *Multiple voices.* Ideally, warnings would be transmitted by a single authoritative voice, but realistically, this does not always happen and cannot be controlled. Advances in ICT and the widespread access to the global media means a break-

Box 1.4 Peace of mind for a tourist paradise

In the Maldives, located in the Indian Ocean south of India, some 300,000 people live on 200 of the 1,200 small islands which make up the country. The densely populated capital Malé is home to one-third of the population. This atoll nation is the wealthiest in the region with a gross domestic product (GDP) per capita of US$ 2,992 and more mobile phone connections than people (Maldives Government, 2008).

Tourism is the single most important industry, contributing around 27 per cent of GDP. Some 92 of the uninhabited islands have been converted to resorts that attract upmarket tourists, whose numbers amount to more than one-fifth of the country's population during the peak winter season. According to the Asian Development Bank, the Maldives was among the countries worst affected by the 2004 Indian Ocean tsunami. Loss of life was small, but about one-third of the population was affected and property damage was estimated at around 60 per cent of GDP (Asian Development Bank, 2006). Ensuring public safety and giving visitors a sense of security are thus high priorities for the government.

The highly dispersed population (it takes 48 hours to go from one end of the Maldives to the other by boat) is one reason why radio and television are less than ideal for public warning. Tourists are unlikely to listen to national channels, and radio and TV sets have to be switched on for warnings to be communicated. Complete mobile coverage of inhabited and resort islands, the near ubiquity of handsets among both citizens and guests, and their ability to sound alerts point to mobiles as an attractive option for early warning.

SMS and cell broadcasts (CB) are two options for public warning via mobiles. The former is better known but is unsuited for public warning (see Table 1).

A recent United States Federal Communications Commission Order on public warning via mobiles found SMS to be unsuitable and indicated that operators should instead use the point-to-multipoint capabilities of networks. CB is the only viable method at the present time. Since handsets incapable of delivering public warnings will have to carry notifications, this has turned the tide among manufacturers and operators in favour of CB.

In consequence, the Telecommunications Authority of the Maldives (TAM) requested LIRNEasia, a regional telecom policy and regulation think tank with expertise in disaster early warning, to identify the preconditions necessary for the use of CB for early warning and to evaluate its potential for commercial applications. The biggest barrier was found to be lack of knowledge. In the tiny but intensely competitive Maldives telecom industry, the operators, each with a customer base less than that of a small city elsewhere, focus almost exclusively on marketing. However, upon learning of the existence of over 66,000 logical CB channels, they quickly realized CB's potential – not only for public warning but for numerous commercial and other applications.

Obviously, the efficacy of a public warning technology rests on the speed and accuracy of warnings and orders issued by government on one side and the readiness to take appropriate action by the populace on the other. Tourist resorts are organized communities with structures for decision-making and taking action. With periodic training and refresher courses, they can be prepared to respond appropriately. Ensuring general community preparedness poses a more difficult challenge.

CB is an intrinsic feature of several networks that are available in the two Maldivian networks. But it must be activated. Most handsets are capable of receiving CB messages as long as the feature is turned on. However, in the early stages, getting customers to turn this function on could be an effective way of educating them about mobile-based public warning.

Following stakeholder meetings that included the sharing of information on the ongoing CB channel-standardization work of the International Telecommunication Union (ITU) and of experience in attempting to use CB for public warning in Sri Lanka, the recommendations to TAM are being finalized. They include the constitution of a 'trust protocol board' to develop the terms of access to the CB broker server. This will ensure security and the conduct of live demonstrations on a test channel, which the public will not see, that are likely to bring up technical issues that require resolution before full-scale implementation is possible.

Once technical implementation is complete, a public awareness campaign will be required to persuade citizens to switch on the CB function in their handsets. It will take time, and the success of ITU's standardization efforts, for all tourists to automatically receive warning messages on their roaming mobiles. A campaign telling tourists how to turn on the Maldivian warning channel will not only enhance their security but also communicate the image of a more caring Maldives. For sustained adoption, it will be necessary for the regulator to continue discussions with the operators to develop a framework for commercial CB applications and to encourage such uses. ■

Table 1

Short message service	Cell broadcast (CB)
Messages sent point-to-point (messages directed to handsets)	Messages sent point-to-area (messages directed to radio cells)
Requires input of recipient phone numbers	Does not require input or knowledge of numbers
Only pre-registered numbers notified	All numbers within a cell notified
Messages cannot be differentiated by location of recipients	Messages can be differentiated by cells or sets of cells
Subject to congestion and thereby delay	Being broadcasts, not subject to congestion
140–160 characters in length. Can concatenate up to five messages	93 characters. Can concatenate up to 15 'pages' to produce a single message of up to 1200 bytes of data
No indication that message is generated by a legitimate authority	Not possible for outsider to generate a cell broadcast so greater authenticity

down in control and potential confusion among target groups. While a single voice may be desirable and may still be possible in some countries with limited access to ICT, it is likely to be increasingly difficult to control.

Major challenges in response capability and preparedness to act

People's willingness or ability to take appropriate actions when warnings are received can be affected by various factors, many of which can be overcome through preparedness. People are more likely to pay attention to warnings if they have been educated about the risks in advance and know what actions to take. Public education campaigns, including inserting disaster risk awareness into school curricula, can build capabilities.

Contingency plans can map out roles and responsibilities in advance and speed the response time, although in many cases, they become routine annual documents rather than living, operational processes. Simulation exercises can be very effective in building response capabilities and bringing preparedness planning to life. They can test the response systems, coordination structures and the knowledge of at-risk populations. While it is not possible to carry out full simulation exercises for every potential risk, a multi-hazard approach can test systems for a variety of threats, including those with relatively low probability.

A lack of options is another challenge to the ability of communities to respond to warnings. While the multiple systems failed during Hurricane Katrina in New Orleans, one of the main reasons the hurricane caused such a major disaster is that poor, disenfranchised populations were without the resources needed to escape. They lacked personal transportation or sufficient money to leave their homes. In many cyclone-prone regions, populations may not heed warnings because there are no viable escape routes or shelters. There is a need to build 'front-line capacity' to ensure people have options to respond when confronted with a warning.

Risk perceptions play a large role in attitudes about heeding warnings, as described above. People may ignore warnings because they have inherently accepted the risk posed by the hazard.

Building response and preparedness capacity before an event requires resources. Very often, massive resources are poured into short-term, post-disaster response while funding for public education on disaster preparedness, contingency planning and simulation exercises is relatively scarce. A separation between the producers or operators of the early warning system and those making funding decisions for preparedness and response activities is common. When funding decisions fall in a different ministry or organization, those controlling the resources may require additional verification or analysis before taking action.

Some of the most effective early response systems occur when information and analysis units are directly tied into funding units. As the 'culture of preparedness' advocated by the Hyogo Framework takes hold, more agencies are linking information to action and pre-positioning response funds ideally to be used even before the disaster strikes. Some pre-positioned funds have been created on a national basis and are being used for *pre-disaster* interventions as well as quick post-disaster response, such as the Humanitarian Response Fund (HRF) in Ethiopia. The International Federation's Disaster Response Emergency Fund (DREF) allows it to call in emergency assets immediately after a disaster – and before, when a warning is received. The DREF can be mobilized by early warnings before disaster strikes, such as the recent allocation of 500,000 Swiss francs for potential flooding in West Africa, based on warnings in the seasonal forecast (see Chapter 3, Box 3.4). While both HRF and DREF are mainly targeted at short-term relief interventions to save lives after a disaster, their ability to release funds pre-disaster is an important step forward.

Efforts to establish epidemic early warning systems for malaria (see Box 1.5), meningitis and diarrhoeal diseases can greatly benefit pre-disaster funding. If warning systems can establish when environmental conditions favour an outbreak of an epidemic, pre-disaster funding can lead to a pre-positioning of vaccines, public education campaigns and advocacy efforts.

Box 1.5 Malaria: early warning and early action in Africa

Malaria is one of the world's biggest killers; about 1 million people die from it every year. It is endemic to several regions of the world, but Africa accounts for an estimated 90 per cent of cases. A malaria early warning system is being tested in several African countries, allowing early action in the right place at the right time.

Malaria is endemic to regions where conditions allow the malaria mosquito to breed and the malaria parasite to be transmitted year-round, so malaria control needs to be routine and ongoing. At the fringes of these regions are areas that are normally free from malaria, but are at risk from malaria epidemics when, from time to time, conditions become favourable (for example, changes in rainfall and temperature).

Where malaria is endemic, people usually have some resistance to the disease, and medical services are used to dealing with malaria. In contrast, when epidemics occur, they affect people with little or no immunity. Medical services, without early warning ahead of an epidemic, can be overwhelmed; thus early warning and early action have a critical role.

Roll Back Malaria, an initiative of WHO, the UN Development Programme, the UN Children's Fund and the World Bank, with more than 90 partners including national ministries of health, has developed the malaria early warning and response system. The system has five components:

- Vulnerability assessment and monitoring help keep track of vulnerable populations ahead of an epidemic.
- Seasonal climate forecasting: since the conditions that lead to epidemics are largely to do with the climate – high rainfall and humidity and warm temperatures favour the malaria mosquito and transmission of the parasite – forecasting can help predict where and when epidemics may occur. Seasonal forecasts predict conditions several months ahead, allowing plenty of time for appropriate early action. But there is a trade-off: the further ahead a forecast predicts, the more uncertainty it contains and the higher the chance that efforts will go to waste.
- Environmental monitoring: like seasonal forecasting, this gives advance warning of favourable conditions and the likelihood of

an epidemic. It has shorter lead times so contains less uncertainty, but also gives less time for preparation to deal with an epidemic.

- Sentinel case surveillance: a rise in malaria cases indicates the start of an epidemic.
- Planning, preparedness and response: this is the early action component, made possible by the early warning system of the first four components.

The system has been introduced in several epidemic-prone African countries, including Botswana, Ethiopia, Madagascar, Mozambique, Namibia, South Africa, Swaziland and Zimbabwe. According to Joachim Da Silva, epidemics and emergency officer of the WHO Southern Africa Inter-Country Malaria Control Programme (IRI, 2007), it is proving successful: "The quality of epidemic response in countries implementing the malaria early warning and response system has improved significantly. National malaria control programmes are able to forecast for the transmission season, detect early epidemics, and mount very effective responses to control them before they get out of hand, and therefore minimize suffering and deaths."

Ethiopia has recently begun to use the malaria early warning system. An estimated two-thirds of its 77 million population are at risk from epidemic malaria. One of the first challenges was that climate service providers and health workers rarely cross paths and would need to collaborate better for the system to be effective. Fundamentally, climate service providers need to provide information that health workers understand and can use. This is being addressed by a new climate and health working group, which brings these communities together.

Early action to combat malaria

National programmes are responsible for monitoring malaria progression throughout a season, with the help of the early warning system tools. When there is the likelihood of an epidemic, staff can begin control activities such as spraying with insecticide and supplying mosquito nets. Emergency mobile treatment centres can be prepared, ready to be moved to where they are needed as soon as an epidemic breaks out.

Early action is also critical at the community level, and this provides an additional challenge in epidemic, as opposed to endemic, areas. Awareness of malaria in epidemic areas – both its symptoms and also effective control measures – is usually low, even among health-care workers, since the disease is relatively uncommon. As some of the most effective control measures can be implemented at the household level (such as sleeping under mosquito nets or taking anti-malarial drugs promptly when symptoms appear), education and awareness-raising at this level are critical early actions that can make a huge difference to the outcome of an epidemic.

The role of the media is, therefore, important. In South Africa, TV and radio are used to warn communities they might be at risk and regular updates on outbreaks are given. In Ethiopia, monthly bulletins on climate conditions and malaria risk are distributed via the RANET web site (http://meteo-ethiopia.net).

Climate change adds a new dimension to early warning and early action for malaria and other climate-sensitive diseases. It remains to be seen how the climate will change in the long term, but it is widely agreed that global warming will continue over the coming decades (see Chapter 4). This has implications for both endemic and epidemic malaria regions, and adds urgency to the need for early action. Whatever the climate brings, reducing vulnerability at the individual, community and national levels is the early action needed. ■

CHAPTER 1

In slow-onset disasters such as drought, it is difficult to define when an 'emergency' begins. Early warning systems monitor a variety of indicators, but without clear indicators to trigger response, it is often delayed until the effects are visible and populations have suffered economic or physical losses. Multiple assessments are carried out, data are collected and analysed to formulate response options while affected populations liquidate assets, pull children from school or migrate to find opportunities. Chapter 5 explores these issues in more detail. Climate change is even slower onset, making it even more difficult to trigger action. Warnings clearly have been sounded at the global level. In some regions, action to support adaptation to climate change is under way but as highlighted in Chapter 4, much more is needed.

Conclusion

Early warning systems continue to evolve. Understanding early warning as a system rather than a technology highlights the need to address risk assessment, communication and dissemination, and preparedness to act with the same level of commitment provided to the technological aspects of early warning. A breakdown in any one of the pillars of early warning can cause warning messages to fail to reach and motivate their intended recipients.

Significant challenges remain, especially as the nature of vulnerability continuously evolves and historical trends no longer provide reliable signals for future disaster occurrences due to climate change. There is no single solution, given the diversity of risks facing virtually every corner of the globe, but global cooperation has helped create systems to better prepare for and mitigate natural disasters. Lessons about multi-hazard approaches and ways to create community-centred early warning structures are being passed from country to country and adapted for local conditions.

Communities and governments, as well as international agencies, play a central role in early warning. At every level, the people involved must work together in a coordinated system to achieve the goal of preventing loss of life and livelihoods from both mega-disasters and the smaller disasters happening every day well away from the media spotlight. Early warning must lead to early action across all timescales, from providing a sufficient notice of an imminent event, to helping societies learn to adapt to climate change. Early warning systems can and do prevent loss of life, but with ever more dramatic and unpredictable disasters, the long-term solution must lie in efforts to reduce people's vulnerability to natural hazards.

The hazards (cyclones, droughts, disease outbreaks, etc.) will continue to occur and may become less predictable and more frequent and intense. The sustainable, long-term solution is to understand households' and communities' vulnerabilities to these hazards and tackle the underlying causes of this vulnerability.

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Sources and further information

Asian Development Bank (ADB). *Maldives: Tsunami summary*. Manila: ADB, March 2006. Available at www.adb.org/media/Articles/2005/6617_tsunami_impact_Maldives/ default.asp?RegistrationID=guest.

Aspinall, W.P. et al. 'The Montserrat Volcano Observatory: its evolution, organization, role and activities' in Druitt, T.H. and Kokelarr, B.P. *The Eruption of Soufriere Hills Volcano, Montserrat, from 1995 to 1999.* London: Geological Society, 2002.

Atwood, E. and Major, A.M. 'Exploring the "Cry Wolf" Hypothesis' in *International Journal of Mass Emergencies and Disasters*, Vol. 16, No. 3, pp. 279–302, 1998.

Burton, I., Kates, R.W. and White, G. *The Environment as Hazard.* London: Guilford Press, 1993.

Christie, F. and Hanlon, J. *Mozambique and the Great Flood of 2000.* Bloomington: Indiana University Press, 2001.

EM-DAT. The OFDA/CRED International Disaster Database. Université Catholique de Louvain, Brussels. Available at www.emdat.be.

Food and Agriculture Organization (FAO), World Organisation for Animal Health (OIE) and World Health Organization (WHO). *Global Early Warning and Response System for Major Animal Diseases, including Zoonoses.* FAO, OIE and WHO, 2006.

Fiske, R. S. 'Volcanologists, Journalists, and the Concerned Local Public: A Tale of Two Cities in the Eastern Caribbean' in National Research Council, *Explosive Volcanism: Inception, Evolution, and Hazards.* Washington DC: National Academy Press, 1984.

Golnaraghi, M. and Migraine, J.B. 'Disaster risk management: an investment in development' in *The Full Picture,* pp. 160–163. Geneva: GEO, 2007.

Golnaraghi, M., Douris, J. and Migraine, J.B. *Saving lives through early warning systems and emergency preparedness.* Geneva: WMO, 2008.

Greek Ministry of Foreign Affairs. *Tsunami Early-Warning System for the Mediterranean, a German Proposal.* Athens: Greek Ministry of Foreign Affairs, 2008. Available at www.aidfunding.mfa.gr/bpufm/pdf/germaniki_protasi.pdf.

Howell, C. *Indigenous Early Warning Indicators of Cyclones: Potential Applications in Coastal Bangladesh.* London: Benfield Hazard Research Centre, 2003.

International Federation of Red Cross and Red Crescent Societies. *Bridging the gap: Integrating Climate Change and Disaster Risk Reduction.* The Hague: Red Cross Red Crescent Climate Centre, 2008. Available at www.climatecentre.org/?page=news_ext&pub_id=154&type=3&view=more.

International Federation. *Early warning > early action.* Geneva: International Federation, 2008.

International Federation. *Survivor's guide: flood alert in Mozambique.* Geneva: International Federation, 2007. Available at www.youtube.com/watch?v=5L_-RdtCf8s.

International Research Institute for Climate and Society (IRI). *Climate Risk Management in Africa: Learning From Practice.* Climate and Society No. 1. New York: IRI, Columbia University, 2007.

LIRNEasia. *Evaluating Last-Mile Hazard Information Dissemination: A Research Proposal.* Colombo, Sri Lanka: LIRNEasia, 2008.

LIRNEasia. *National Early Warning System: Sri Lanka.* Colombo, Sri Lanka: LIRNEasia, 2005. Available at www.lirneasia.net/projects/2004-05/national-early-warning-system/.

Maldives Government. *Maldives at a Glance, August 2008*. Department of National Planning, Republic of Maldives, 2008. Available at http://planning.gov.mv/en/images/stories/publications/mag/august2008.pdf.

Newhall, C.G. and Punongbayan, S. (eds). *Eruption Hazard Assessments and Warnings Fire and Mud. Eruptions and Lahars of Mount Pinatubo, Philippines.* Seattle: University of Washington Press, 1997.

RAIPON and United Nations Environment Programme. *Indigenous Knowledge in Disaster Management.* 2006. Available at www.raipon.org/ikdm/Default.aspx.

Rangarajan, S. and Rao, M. *Addressable Radios for Emergency Alert (AREA): Early Warning: Challenges, Options & Solutions.* Paper presented at 3rd Global Knowledge Conference, Kuala Lumpur, Malaysia, 11 December 2007.

Samarajiva, R. and Waidyanatha, N. *Early warning systems in disaster-risk reduction.* Paper presented to the IDRC-CIDA workshop, Moratuwa, Sri Lanka, 12 July 2007.

United Nations (UN). *Global Survey of Early Warning Systems: An assessment of capacities, gaps and opportunities toward building a comprehensive global early warning system for all natural hazards.* Bonn: UN, 2006.

UN Educational, Scientific and Cultural Organization (UNESCO). *Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS).* Report on the 4th Session, Lisbon, 21–23 November 2007. Paris: UNESCO, 2008.

UN International Decade for Natural Disaster Reduction (IDNDR). *Declaration of the Potsdam Early Warning Conference, 11 September 1998.* Potsdam: IDNDR, 1998.

United Nations International Strategy for Disaster Reduction (UNISDR) and German Committee for Disaster Reduction. *Early Warning – From concept to action: The Conclusions of the Third International Conference on Early Warning.* Bonn: UNISDR, 2006.

UNISDR and German Committee for Disaster Reduction. *Early Warning as a Matter of Policy: The Conclusions of the Second International Conference on Early Warning*. Bonn: UNISDR, 2004.

UNISDR. *Words into Action: A guide for implementing the Hyogo Framework.* Geneva: UNISDR, 2007.

UNISDR. *Milestones and first steps of early warning matters – timeline*. Geneva: UNISDR, 2006a.

UNISDR. *Developing Early Warning Systems: A Checklist.* Geneva: UNISDR, 2006b. Available at www.unisdr.org/ppew/info-resources/ewc3/Checklistenglish.pdf.

UNISDR. *Hyogo Framework for Action: Building the Resilience of Nations and Communities to Disasters*. Geneva: UNISDR, 2005.

UNISDR. *Terminology: Basic terms of disaster risk reduction 2004*. Geneva: UNISDR, 2004. Available at www.unisdr.org/eng/library/lib-terminology-eng- 2004.htm.

United States Geological Survey (USGS). *Historic Worldwide Earthquakes.* Sioux Falls: USGS, 2008. Available at www.earthquake.usgs.gov/regional/world/historical_mag.php.

van Aalst, M. 'The impacts of climate change on the risk of natural disasters' in *Disasters,* Vol. 30, No. 1, 2006.

Voight, B. 'The 1985 Nevado-Del-Ruiz Volcano Catastrophe – Anatomy and Retrospection' in *Journal of Volcanology and Geothermal Research,* Vol. 42, Nos. 1–2, pp. 151–188, 1990.

World Health Organization (WHO). *Early Warning and Response to Outbreaks and other Public Health Events: A Guide.* New Delhi: WHO Regional Office for South-East Asia, 2008.

WHO. *World Health Report 2002.* Geneva: WHO, 2002.

WMO. *Capacity Assessment of National Meteorological and Hydrological Services in Support of Disaster Risk Reduction.* Geneva: WMO, 2008.

WMO. 'Preventing and Mitigating Natural Disasters' in *WMO Bulletin*, Vol. 55, No. 1, January 2006.

Xu, T. 'Managing disaster risk in a mega-city' in *WMO Bulletin*, Vol. 55, No. 4, October 2006.