Chapter 5
Early Warning Systems Defined

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Abstract This chapter defines and describes early warning systems (EWS) by examining structures and functions of EWS. The focus of this book is on climate change, but other hazards help to better illustrate and understand EWS in the context of climate change. These include hazards which manifest rapidly, such as tsunamis, as well as creeping hazards which manifest slowly, such as drought. The fundamental tenet is that each EWS needs to be viewed as a social process which often involves technical components embedded in their social context. That leads to a preference for a 'First Mile' approach for designing EWS, which involves communities from the beginning of developing an EWS, rather than a 'Last Mile' approach, which adds people and communities towards the end of the design process. By keeping people and communities at the centre of an EWS from the beginning, the EWS can contribute to daily life and livelihoods, thereby supporting wider disaster risk reduction and sustainable development endeavours, rather than being a separate system waiting to be triggered only when a hazard appears. Yet any EWS has limitations. Those limitations need to be recognised and overcome through other approaches, with possibilities being to consider 'medium warning' and 'late warning' systems rather than just early warning.

Keywords Early warning systems • EWS • Warnings

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5.1 What Is an EWS?

5.1.1 EWS in General

A universally accepted definition of an early warning system (EWS) does not exist and probably never will exist.

Box 5.1 EWS Definitions—And Lack Thereof!

The United Nations International Strategy for Disaster Reduction (UNISDR 2012: online) defines an early warning system to be 'The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss'. Interestingly, The United Nations Department of Humanitarian Affairs (DHA 1992) defines 'warning' but neither 'warning system' nor 'early warning system'.

As implied by UNISDR's (2012) definition, a fundamental part of an EWS generally accepted by most disaster risk reduction (DRR) literature (e.g. Gruntfest et al. 1978; Lewis 1999; Wisner et al. 2004, 2012) is that EWS is a social process aiming to address the need to avoid harm due to hazards. The social process occurs at a variety of spatial scales, from individuals in isolated villages without electricity through to the global UN processes working with governments.

Emphasising the social process contrasts with technical views that an EWS comprises only the technical equipment detecting a hazard event and sending the hazard parameters to authorities for decision-making. Instead, the 'system' of the EWS needs to include the decision-making authorities and their decision-making processes, along with many other social aspects before and after a hazard event occurs.

EWS as a social process embraces, rather than precludes, the technical aspect—but the technical aspect is always placed in its social contexts. The technology might be chains strung across a river which create noise when the river reaches a certain height, alerting people. The technology might be the sophisticated international systems of seismographs and buoys telemetering real-time data of earthquakes and tsunamis to monitoring stations.

The onset time of the hazard is one input into the level of technical expertise required within an EWS, although some research suggests that too much lead time can lead to potentially dangerous behaviour (Hoekstra et al. 2011). For instance, tornado warnings generally give minutes of lead time for a warn-on-detection system or hours of lead time for a warn-on-forecast system. Hurricane warnings are on the order of hours to weeks. Drought warnings are sometimes issued months in advance.

Yet an EWS does not start with a hazard manifesting. As Mileti et al. (1999, pp. 174–175) wrote:

> The most effective warning systems integrate the subsystems of detection of extreme events, management of hazard information, and public response and also maintain relationships between them through preparedness.

EWS as a social process means that it should be ongoing, engrained in the day-to-day and decade-to-decade functioning of society—even while recognising that this ideal is rarely met in practice. To understand the operationalisation of this ideal for an EWS, the phrase itself needs to be broken down.

Box 5.2 EWS Questions

- How early is 'early', especially in relation to the timing of the warning compared to the timing of the hazard—and of the vulnerability?
- What constitutes a 'warning'—just the information about the hazard or more?
- How is that warning triggered?
- What is meant by a 'system': formal, informal, quantitative, qualitative, or anecdotal?
- With EWS engrained in a community, what else might it contribute to, other than the strict EWS functions?

The answers to the questions in the box are contextual, varying amongst social settings and also depending on the hazard or hazards to which an EWS is geared. For example, the USA runs two official tsunami warning centres:

(i) The West Coast and Alaska Tsunami Warning Center based in Alaska which is responsible for issuing tsunami warnings for most American and Canadian coasts, but not including Hawai'i, the US Pacific territories, and Canada's Arctic.
(ii) The Pacific Tsunami Warning Center in Hawai'i which is responsible for issuing tsunami warnings for much of the rest of the world, including the Pacific and Indian Oceans.

These centres' responsibilities include sending out messages regarding tsunamis as soon as possible, usually within minutes, after a potentially tsunami-generating earthquake. As such, 'early' means immediately after a hazard manifests while 'warning' means a message with quantitative hazard parameters that identifies coastlines which might experience a tsunami.

Other warning messages include specific actions which people should take due to the hazard. For instance, when the Pacific Tsunami Warning Center provided tsunami warning messages for Aceh, Indonesia, on 11 April 2012, the Indonesian authorities translated the messages into the specific action of ‘evacuate the coastal areas now’. Some EWS incorporate pre-hazard information on actions to be taken on an ongoing basis. The Scottish Environment Protection Agency’s flood EWS includes ‘Be flood aware’ and ‘Be flood prepared’ advice which is always valid, irrespective of the status of flood alerts or flood warnings.

Differing views exist on how extensive EWS information should be. Should it provide only basic information? Should it ensure that this information reaches all target audiences, is understood correctly, and is acted upon appropriately and in a timely fashion? In the case of Indonesia’s tsunami warning, issuing evacuation notices for the coast might not be enough if people do not know evacuation routes, how to evacuate, where to go, or what to bring with them. Those living several hundred metres away from the shoreline could still be vulnerable to a tsunami, yet might not consider themselves to be within a coastal area and therefore needing to evacuate.

Cuba, under Fidel Castro, developed a comprehensive EWS for hurricanes, saving thousands of lives by making people aware of approaching hurricanes and clearing people out of threatened locations, even at relatively short notice (Aguirre 2005; Thompson and Gaviria 2004). The authoritarian dictatorship permitted that EWS to function, because the government was able to implement, without question, what was needed to evacuate people—and the people tended to obey what they were told to do.

That does not mean that a single agency should or could always be responsible for all EWS-related activities (e.g. communication and action). Additionally, while there may be an officially designated EWS, official EWS authorities for certain hazard(s), or certain types of warning messages, there are many other routes and groups—quasi-official, unofficial, and anecdotal—through which people receive EWS-related information and advice. These routes function continually, not just when a hazard manifests. Consequently, all those involved in an EWS should interact and let each other know what is needed, continually rather than only after a hazard, in order to avoid any misunderstandings or miscommunications. Such problems have indeed arisen throughout the history of EWS.

EWS garnered much attention in the 1970s and 1980s during the droughts and famines in the West African Sahel and the Horn of Africa. In response, famine early warning systems were created across the region as well as within donor countries and international organisations. Holloway (2000) describes how a drought warning system for southern Africa led to a coordinated regional response which prevented a major drought from becoming a major drought disaster from 1991 to 1993. In this case, the EWS functioned across tasks: providing hazard information, indicating needed actions, and effecting those actions.

Box 5.3 EWS in Ethiopia

Ethiopia has long suffered droughts and famines, but two in recent history spurred the development of EWS. In 1973–1974, approximately 200,000 people died in Ethiopia compared to 1983–1985 which might have killed two to five times as many people. Political pressure from the first disaster led to the establishment of an Ethiopian government commission that tried to consolidate information from various government agencies into a warning system regarding the country's food situation. Inhibiting factors included poor information, weak institutional collaboration, and unclear indicators for issuing a warning (Metcalf et al. 1989). After the second disaster, the US government created the Famine Early Warning System (FEWS) which even today focuses mainly (although not exclusively) on Africa, in order 'to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues' (http://www.fews.net/ml/en/info/Pages/default.aspx?l=en).

As technology has evolved, EWS have evolved. Remote areas could originally be reached immediately only via radio or satellite phone. Now, mobile phone coverage permits text messages—or even audio or video files with warnings, especially to target populations with less literacy—to reach large swathes of the Earth's land. New products are being developed which automatically identify any mobile phones in a location and send a geographic-specific warning to those within a certain boundary. The importance of these developments needs to be balanced with the challenges for those who cannot afford mobile phones, those in areas without coverage, and areas where infrastructure maintenance is not reliable. Technological developments are important for EWS, but the latest technology cannot be assumed to be omnipresent, reliable, accessible, or affordable. As stated above, the technical aspect of EWS should always be placed in its social contexts.

When examining the structure and function of an EWS, further discussion is required regarding both the hazard and vulnerability factors. One hazard factor is the frequency of the hazards about which the EWS warns. A misunderstanding about EWS is that they exist to be activated only when a hazard manifests. According to this myth, the EWS is not needed during periods without the hazard; EWS have nothing that they should or could be doing. The reality is that the EWS should remain an active part of the community at all times. It can be used to educate people about hazards and vulnerabilities, for training about disaster risk reduction and disaster response, to run drills, to gather baseline data, and to further map and update a community's hazards, vulnerabilities, and risks. That is part of the social process of EWS. Similarly, those involved in operating an EWS can approach the media and other sectors of society to enquire how to make the system more effective, what people's changing needs are, and how to keep the EWS as part of the community consciousness, irrespective of hazard frequency.

One component of that awareness, continual functioning, and embedding in its social contexts, is that any EWS must serve multiple audiences. That is important for vulnerability, because groups of people have different forms and degrees of vulnerabilities and capacities. All communities have different groups with different interests, meaning that no homogeneity amongst needs or knowledge can be assumed in any community (Walmsley 2006). Ensuring that an EWS serves all sectors of a community can be challenging, considering different ages, different genders (male, female, and non-traditional gender identities), people with mental and physical disabilities, prisoners, homeless, and representatives of all religious, ethnic, caste, and cultural groups. People speak many languages and dialects. Visitors to a community, such as tourists and businesspeople, might not speak any of the local languages.

5.1.2 EWS for Creeping Hazards Including Climate Change

Because EWS must focus on vulnerabilities and be used in vulnerability reduction, as part of the day-to-day lives of the people which it serves, EWS can function for long-term, slow-onset hazards in addition to the quickly manifesting ones such as earthquakes and tornadoes. Long-term hazards which can change baselines and indicate trends are referred to as 'creeping changes'. In addition to climate change, CEPs include soil degradation and drawdown of water supplies. These changes all occur with small steps, yet cumulate into major problems, which are often only recognised as being problematic once a specific threshold is crossed without knowing (Glantz 1994a, b).

Climate change is one creeping change. Thresholds which climate change appears to be heading towards include an ice-free Arctic Ocean in the summer, the melting of permafrost, the contamination of atoll water supplies with saltwater due to sea-level rise, and large-scale deaths of coral reefs. Other potential thresholds are Antarctic or Greenland ice sheet collapses and the inundation of low-lying areas of megacities such as London, New York, and Djakarta.

How do EWS function for creeping hazards such as climate change? There are two main ways that traditional EWS could be applied, leading to a wider discussion of what an EWS ought to be rather than what it has been traditionally.

First, climate change is not necessarily a hazard per se, but it significantly influences other hazards. Some hazards might become easier to deal with, while others might become harder to deal with—or parameters might change in different ways. For instance, Knutson et al. (2010) describe how climate change is likely to decrease the frequency of Atlantic hurricanes while increasing the severity of hurricanes which do form. Rainfall is expected to increase in volume and intensity in northern Scandinavia, leading to worse floods, but less snowfall due to warmer temperatures could lead to fewer blizzards—unless cold extremes increase even while the average temperature increases. The changes which climate change can bring to hazards are complex!

Since climate change is more of a hazard influencer than a hazard, does that mean that an EWS for climate change in general might not be relevant? Instead, would it be better to create, EWS for different hazards, each of which factors in changes to their respective hazards due to climate change as well as due to other factors? These questions lead to the second point.

Climate change might not be a hazard itself, yet the process could still be warned about, partly to tackle the causes and partly to deal with the consequences. As such, the Intergovernmental Panel on Climate Change (IPCC) might serve as a warning system for climate change by assessing and synthesising climate change science and indicating actions that are needed based on the science.

The difficulty with these two points on climate change EWS is that they both focus on hazards without fully accounting for vulnerability. The previous section highlighted the importance of using EWS for vulnerability reduction, rather than expecting EWS to apply to hazards only. If EWS for climate change and other creeping and non-creeping hazards were created in such a way that they tackled all vulnerability and contributed to day-to-day development, then by definition, all hazards and hazard generators would be encompassed.

As such, there is no need to separate climate change from other hazards and hazard generators, or to deal with climate change in its own domain, silo, or discipline. Instead, climate change is one aspect of all the potential hazards faced, and dealing with climate change (climate change adaptation) becomes enfolded within DRR. After all, DRR by the definition given earlier includes all climate change adaptation activities. Yet DRR itself cannot be isolated and is part of development-related endeavours, bringing the discussion full circle that EWS need to include potential climate change impacts—but only to ensure that dealing with climate change is part of the ongoing community EWS social processes.

An EWS for climate change or climate change-related changes therefore will not look much different from what most EWS should look like. It will look different from the form of most EWS today, because an EWS involving climate change is a social process integrating technical monitoring and information into it. The EWS will include education and exchange, for example, so that people living on permafrost are warned about the potential melting over the next decades and prepare their communities for it. The EWS will include adaptation to new hazard regimes, so that atoll communities are warned about potential changes to their freshwater supplies, coral reefs, and coastlines. They can then begin to act now to shape their communities in such a way that they will not experience disasters, whether or not the projections for climate change lead to projected thresholds—or even if climate change leads to worse thresholds being crossed. It might be that communities decide to relocate, such as Newtok in Alaska and the Carteret Islands in Papua New Guinea are doing at the moment. It might be that communities decide to invest in desalination plants that they can maintain and repair themselves. It might be that communities take the risk of a major catastrophe, such as a drought or coral reefs dying, and accept the lethal consequences if one strikes.

The key is that, in theory, an EWS for creeping changes gives more time to plan a response and to integrate that response into day-to-day life and longer-term development. That lesson needs to be transferred to EWS for sudden-onset hazards to move away from traditional approaches focusing on only the immediate hazard and emergency response into EWS which incorporate training, community building, baseline data collection, and livelihood support over the long term—irrespective of the time scale of any given hazard. If that were achieved for sudden-onset hazards, then lessons can be transferred back to the creeping hazards to try to reduce the impacts of the creeping hazards long before the thresholds are crossed.

Given that EWS must effectively serve multiple audiences in multiple ways, covering different time scales, what approaches can be used to achieve that?

5.2 Approaches for EWS

5.2.1 Characteristics

Box 5.4 The Fundamental Tenet of an EWS

A fundamental tenet suggested for EWS is that the information that it provides, either in the context of a hazard manifesting or long before that, should address the five Ws and one H: what, when, where, who, why, and how:

- What is happening with respect to the hazard(s) and vulnerability/vulnerabilities of concern?
- When are impacts likely?
- Where are the locations at risk?
- Who is at risk?
- Why is this a threat, i.e. why are there vulnerabilities?
- How can the EWS be effective—not just for the specific hazard manifesting, but also as a long-term social process?

Each question within the fundamental tenet of an EWS is difficult to answer for any given context. Answering them collectively and completely is unlikely to be feasible for any specific EWS. Nonetheless, it is possible to move forward with conceptualising and designing an EWS, recognising the information that ought to be available ideally, even if some of the answers are fuzzy in reality. Consequently, from an operational perspective, characteristics of an EWS converge on the following (e.g. Gruntfest et al. 1978; Gruntfest and Ripps 2000; Lewis 1999; Mileti et al. 1999; Wisner et al. 2004, 2012):

Continuity: An EWS must operate continually, even though the hazard of concern may occur only intermittently or rarely. With EWS as a social process embedded in the community, and with vulnerabilities ever-present, an EWS cannot exist intermittently or rarely to be visible only when a hazard manifests. Bangladesh's cyclone warning and shelter system provides an example. Haque and Blair (1992) describe how Bangladeshis were often reluctant to evacuate to flood shelters, not because they disbelieved the warnings, but because they feared that their property left behind would be looted, while also being concerned that they would need to pay rent in order to use the shelters. Now, Bangladesh's cyclone warning and shelter system incorporates day-to-day aspects of life (Akhand 2003): Disaster awareness education is included as part of the EWS, plus some of the shelters are in schools, colleges, offices, and community centres, so that people are familiar with these locations and do not see the shelters as being strange or frightening.

Timeliness: For a warning to be useful, information must provide enough usable lead time for those at risk to decide whether and how to react. This characteristic varies from hazard to hazard and from vulnerability to vulnerability. For tornadoes, minutes are needed to reach a shelter—longer if the whereabouts of shelters are not known, if no formal shelters are nearby, or if people have limited mobility. Many tornado shelters—particularly informal shelters such as ditches—are not particularly hospitable (so people might not want to stay in them for very long) nor are they easy to reach for people with limited mobility. For hurricanes on a trajectory towards major cities, evacuation can take a few days, which is usually how much lead time can be provided with a fair degree of certainty. That does not preclude last-minute trajectory changes which frequently occur. On the vulnerability side, it is often harder for less affluent people to evacuate because they do not have access to private transportation.

For the El Niño Southern Oscillation (ENSO) phenomenon, forecasts with reasonable confidence can sometimes be made months ahead of time, giving people a chance to change the location or type of crops that they plant, the water that they store, and the ploughing techniques that they use. Recent migrants, forced or voluntarily, might be less able to use such information because they have not lived in the location long enough to know how to adjust their activities in response to the warning. Climate change has given humanity decades of lead time and there are clear directions which could be taken, and which some groups are taking, with respect to reacting to that warning.

Not all hazards give a lead time commensurate with the action time. Flash floods in mountainous regions might have 2–20 min of lead time following a localised cloudburst, giving little time to climb to higher ground—even less opportunity if you have difficulty climbing. On 17 July 1998, several minutes after an offshore earthquake, a large tsunami inundated parts of coastal Papua New Guinea which lacked tall buildings or higher ground. Even if a tsunami warning had been issued instantaneously following the earthquake, there would not have been sufficient lead time for people to reach higher ground. Over 1,500 people died.

Box 5.5 Key Elements of an EWS

- Transparency
- Integration
- Human capacity
- Flexibility
- Continuity
- Catalysts/patterns
- Timeliness

Transparency: The process of early warning, and what is and what is not provided, needs to be explicit and entirely open to media and public scrutiny. It is an open question whether or not transparency means that all information is provided to everyone at all times. Providing the general public with raw, unprocessed data without appropriate interpretation or guidance can lead to confusion, misperceptions, and misapprehensions. While panic is rare, taking the wrong action, however, rationalised, can be lethal. On the other hand, withholding information can also lead to confusion, misperceptions, and misapprehensions.

The warnings and responses to the Severe Acute Respiratory Syndrome (SARS) outbreaks in Hong Kong and Toronto in 2003 demonstrate the problems that can result with both too little and too much information (Naylor et al. 2004). Information about a disease outbreak in southern China did not reach the Hong Kong authorities until a few months after authorities in China were informed. Too little and delayed information hampered an adequate response, promoting the spread of the virus. In contrast, in Toronto, lack of coordination of health-care providers meant lack of coordination of information with those responding duplicating efforts to obtain, record, analyse, and respond to information regarding cases and the virus. Certainly, transparency means that those with EWS-relevant information need to be prepared to provide a record of the information that they had and when they had it, in order to seek constructive feedback for continual improvement, rather than a blame game and punishment (e.g. Anderson 1969).

Integration: An EWS must be integrated into communities and society, so that it contributes to, rather than interferes with or is separate from, day-to-day life. EWS as a social process needs to be viewed as a subsystem within larger social and cultural (including economic and political) contexts.

Human capacity: Appropriate staffing is mandatory for all EWS, with the expertise of the personnel commensurate with the vulnerability/vulnerabilities and hazard(s) of concern.

Flexibility: An EWS needs flexibility to expand its activities to other vulnerabilities and other hazards, as and when needed.

Catalysts/Patterns: There is a need for a defined 'triggering' mechanism or regular pattern for sending out information. A trigger could be anything from a quantitative indicator to an anecdotal comment. A regular pattern needs to be frequent enough to keep people engaged and familiar with the messages, but not so frequent so that people get irritated or ignore the large volume of messages. The information sent out is not necessarily only about a specific vulnerability or hazard. It could also be a reassuring message that 'no hazard is imminent' or 'vulnerability has been reduced'. 'All clear' or 'improvements have happened' messages are indeed important components of EWS and they, too, need defined triggering mechanisms or regular patterns. For a hazard example, when Mount Pinatubo in the Philippines was ramping up to a major eruption in 1991, different warning alert levels were developed and issued. After a higher alert level was decided, the EWS forbade the alert level to drop lower until a mandatory waiting period had elapsed of 72 h (from Alert Level 3 to Alert Level 2) or 1 week (from Alert Level 4 to Alert Level 3) (Punongbayan et al. 1996; this alert level system has now been entirely revised). Since explosive volcanoes can often quieten down for a short time before a massive explosion, that delay helped to avoid complacency.

One challenge which every EWS needs to address explicitly is how to define success. From a hazard perspective, so-called near misses (such as when a warning was not issued, but it was nearly needed) and false alarms (such as when a warning was issued, but it was apparently not needed) should be defined for the EWS and described as part of the EWS' performance metrics. Yet it is not clear that either near misses or false alarms indicate failure (Handmer 2000).

Barnes et al. (2007) argue that, for US tornadoes, the way in which 'false alarms' are measured and recorded does not do justice to forecasting accuracy and ability, thereby obscuring instances where people did need to take action even without a tornado touchdown nearby. They also suggest that so-called false alarms for tornadoes in the USA do not make people less likely to respond to tornado warnings in the future; that is, their evidence is that the 'Crying Wolf' syndrome is not usually a concern. In contrast, Simmons and Sutter (2009) found that a higher, recent false alarm rate for tornadoes in the USA significantly increases casualties from tornadoes in that area, suggesting that so-called false alarms for tornadoes do make people less inclined to react to subsequent warnings. The discrepancy could be a result of people's expectations in terms of an EWS' structure and function not being communicated properly, leading to expectations which cannot be fully met. As such, no specific or universal answers can be given regarding what 'failure' means for an EWS.

Similarly, metrics for 'success' can be defined only for each specific context. During the 2004 Indian Ocean tsunami, the Pacific Tsunami Warning Center filled its mandate admirably and without flaw, issuing international warnings for a major tsunami within minutes of the earthquake and using all available channels to disseminate the message. Yet places such as Thailand and Sri Lanka did not evacuate coastal areas despite having hours of warning lead time before the tsunami struck.

The reasons are complicated, but focus on the fact that, long before the earthquake and tsunami, an international tsunami warning system had been assumed to stop and to be successful with the issuing of information to authorities soon after an earthquake, so the Pacific Tsunami Warning Center had no mandate, resources, assistance, support, or expertise to go further (Kelman 2006). Realising the horrendous danger, the staff nonetheless tried desperately to improvise, but as one example indicating why the message did not get through, phones were not answered due to the holiday season. As such, the Pacific Tsunami Warning Center had a huge success, but the EWS system overall—which goes far beyond the Pacific Tsunami Warning Center and the authorities with whom they communicate—undoubtedly failed miserably, leading to a horrendous death toll.

The consequent lessons are the standard ethos that EWS are much more than issuing information on the hazard and that the full EWS cannot start after the hazard has manifested. As Maskrey (1997, p. F-22) writes, 'Early warning systems are only as good as their weakest link. They can, and frequently do, fail for a number of reasons.'

5.2.2 *Miles and Centredness*

Many ways of enacting an EWS are discussed. A popular plea is for 'The Last Mile'. The Last Mile of EWS suggests that plenty of relevant material exists for, and plenty of efforts are put into implementing, an EWS, but a chasm nonetheless exists in getting the information to the people who need it when they need it, in order to produce appropriate responses. The argument is that this identified gap ought to be filled by closing The Last Mile between the knowledge's origin and the places and people where EWS knowledge needs to reach.

There are two flaws with The Last Mile's approach. First, it assumes that all relevant EWS knowledge is external to communities, despite extensive documentation on the necessity of incorporating local knowledge into EWS without relying exclusively on local knowledge (e.g. Gruntfest and Ripps 2000; Wisner 1995). Second, The Last Mile implies that the people who need the EWS are the last to be involved, simply by being an add-on to a system constructed according to external specifications. Instead, the people who are affected by hazards, who have the vulnerabilities, and who are served by the EWS should be involved as the central component and should be involved from the beginning of the EWS design and operation. This approach is termed 'The First Mile' (e.g. Loster 2012). The key is that the people who need EWS information can assist in providing that information and they should be involved as the first, not last, step of setting up and operationalising an EWS.

In that respect, The First Mile differs substantively from The Last Mile due to the different process of creating the EWS from the beginning. That holds true even if the technical, operational, and management approaches of the First Mile EWS and The Last Mile EWS have significant similarities and overlaps. The difference is

Table 5.1 EWS elements according to the UN (UN 2006, p. 2)

Risk knowledge	**Monitoring and warning service**
Systematically collect data and undertake risk assessments • Are the hazards and the vulnerabilities well known? • What are the patterns and trends in these factors? • Are risk maps and data widely available?	Develop hazard monitoring and early warning services • Are the right parameters being monitored? • Is there a sound scientific basis for making forecasts? • Can accurate and timely warnings be generated?
Dissemination and communication	**Response capability**
Communicate risk information and early warnings • Do warnings reach all of those at risk? • Are the risks and the warnings understood? • Is the warning information clear and useable?	Build national and community response capabilities • Are response plans up-to-date and tested? • Are local capacities and knowledge made use of? • Are people prepared and ready to react to warnings?

support from the people using and affected by the EWS, in that an EWS in which people were involved from the beginning is much more likely to be accepted and successful than a system imposed on people from the outside.

That leads directly to the conceptualisation of 'People-Centred Warning Systems' (Basher 2006). Basher (2006, p. 2170) describes four inter-related and interacting elements of an EWS to ensure that people are at the centre of it from the beginning, rather than being an afterthought at the end:

- 'Risk knowledge: knowledge of the relevant hazards, and of the vulnerabilities of people and society to these hazards'.
- 'Monitoring and warning service: a technical capacity to monitor hazard precursors, to forecast the hazard evolution, and to issue warnings'.
- 'Dissemination and communication: the dissemination of understandable warnings, and prior preparedness information, to those at risk'.
- 'Response capability: knowledge, plans and capacities for timely and appropriate action by authorities and those at risk.' (Table 5.1)

This description certainly puts forward numerous buzzwords without clearly indicating what they mean in practice, but some solid and needed elements emerge. First, the recognition that understanding vulnerabilities as well as hazards is important for EWS. Second, the importance of understandable communication, namely on the people's own terms. Third, the ability to respond appropriately to information given, which can only be developed by having an EWS incorporate training, education, and awareness as a continual process, not just once or after a hazard manifests. One element, foreseeability, could be highlighted further so that it becomes an integral component of ensuring that an EWS helps disaster risk reduction and vulnerability reduction in addition to disaster response.

5.2.3 Foreseeability

In the context of law, Gifis (1991, pp. 195–196) writes ‘Foreseeability encompasses not only that which the defendant foresaw, but that which the defendant ought to have foreseen’. The notion of foreseeability is often interpreted as a qualitative expression of probability, in order to determine accountability or fault when someone has been injured or killed or when property has been damaged. That clearly applies to disasters as well, meaning that foreseeability is relevant for EWS.

If it is reasonable to expect that there are likely to be adverse consequences from people’s vulnerability when a hazard manifests, and no steps are taken to minimize those impacts or to reduce the vulnerability, then do those with the power to act beforehand have responsibility for the resulting disaster? The case study from Holloway (2000) of the impending drought in southern Africa from 1991 to 1993 is instructive. The famine consequences of the drought were foreseeable and were part of the warning. Those with the power to act did so, averting a catastrophe.

In contrast, similar foreseeability took place in mid-2002 leading to warnings that famine was a strong possibility for Zimbabwe. Previous years of political changes in land use, linked to and part of dictatorial and corrupt governance from Zimbabwe’s then-President, Robert Mugabe, had already set the stage. The overall indication was that food production was expected to decline across the country. Then, came a forecast for the onset of El Niño later that year which would likely lead to a drought across southern Africa, starting in the growing season and continuing into 2003. Due to the EWS in place, which had long been part of southern Africa’s food security, a strong possibility of severe food shortages in Zimbabwe, as well as in other countries across the region which depended on Zimbabwe’s food exports, was foreseen.

Despite the foreseeability and warnings, Mugabe and his government did little to avert the crisis (see background and details in Howard-Hassmann 2010). By October 2003, 50 % of Zimbabwe’s population was unable to meet its food needs. The food shortages continued for several years afterwards, particularly as Mugabe continued to interfere with farming, food distribution, and humanitarian aid. The EWS was close to an embedded social process, could do its job (see Holloway 2000), and did its job. But even understanding what the situation would entail, the leaders in power in Zimbabwe chose not to avert the foreseeable and preventable disaster. It is an open question regarding success or failure.

The key question for foreseeability and EWS is how to get those with the power to act on qualitative expressions of probability to actually act appropriately. Using EWS to identify and act on foreseeable hazards will also better connect EWS to wider DRR and development activities, including dealing with climate change. With climate change, though, we are again seeing those with the power to act on qualitative expressions of probability failing to act.

5.3 EWS for DRR and Sustainable Development

Concerted, long-term effort is needed to ensure that EWS not only address known, perhaps imminent threats, but also are available to address unusual hazard occurrences and to contribute to vulnerability reduction—continually. From the beginning, EWS should be planned as integrated components of communities, rather than as top-down and external impositions relying on technology which is divorced from a community's day-to-day activities and needs. In particular, the EWS should be made relevant to daily livelihoods and needs, while recognising how different sectors within a community communicate and trust, or do not trust, certain information types from certain sources. That can be done by including education, awareness, and continual data collection within an EWS so that it becomes familiar to and accepted by the community.

Sometimes, the EWS is embedded directly in knowledge indigenous to a community, as shown by an example from Gaillard et al. (2008). Simeulue is an island off the west coast of Aceh, Indonesia, which was the worst-hit location during the 26 December 2004 earthquake and Indian Ocean tsunami. Simeulue's indigenous people had experienced a devastating tsunami on 4 January 1907, resulting in stories being passed down of what to do when the earth shakes as well the coining of a new word *Smong* which refers to three stages. The first stage is ground shaking, as happens during a strong, nearby earthquake. Then, the sea would quickly draw back from the shoreline as the second stage. The third stage is that a powerful, large wave would strike, inundating the coastline. Consequently, Simeulue's indigenous people know that following ground shaking, particularly if the sea recedes, they need to seek higher ground. They did so on 26 December 2004, resulting in only a handful of casualties on the island, mainly due to the earthquake. *Smong*, the new word and the knowledge embedded in the community leading to appropriate action, is the EWS.

Naturally, any EWS has limits. Regarding *Smong*, not all tsunamis result in the sea retreating before the waves strike. As well, sea behaviour might not be visible at night. Nonetheless, Simeulue represents an indigenous and embedded EWS, with the system needing nothing more than collective, credible, community knowledge.

Box 5.6 An Indigenous EWS

Mercer and Kelman (2010) describe an indigenous warning system for Baliau community on Papua New Guinea's Manam Island. The villagers know that the volcano is active and they monitor it by virtue of living beside it. As with most people in PNG, they have strong oral traditions and they have passed down through generations many stories relating the meanings and interpretations of the volcano's behaviour. In 2004, the volcano erupted necessitating an evacuation. Baliau villagers state that they knew that the eruption would happen due to (Mercer and Kelman 2010, p. 417):

> warning signs including blue smoke rings, grass dying around the top of the volcano, a continuous low tide and a very hot dry season.

Even in places with full access to and use of the latest technology, from real-time satellite monitoring to Internet-connected handheld electronic devices, people use many information sources to create their own warning information and action contexts and decisions. Rumours from neighbours and relatives can be trusted more than official bulletins. For instance, experience from Australian floods indicates the high percentage of people receiving warnings through informal sources (Handmer 2000). Similarly, people might accept and trust warning-related information, but be unwilling to act on it for sensible reasons, as described earlier for Bangladesh. As also described earlier, Bangladesh is nonetheless improving in connecting cyclone warning and response systems to day-to-day life. Similarly, Wisner et al. (2004) explain how some Central American locations could connect water management improvement with a flood EWS, embedding the EWS in the community's daily life.

Such operational suggestions for EWS as a social process provide the basis for pursuing the long-term warning system process, integrating EWS and sustainability endeavours, so that EWS become part of, and continually serve, the community, rather than systems waiting to be triggered externally only when a hazard manifests.

In fact, it is important to go beyond people-centredness for EWS in order to include community-centredness. That is not to say that the community always represents every individual. As per the discussion earlier, all communities are heterogeneous. Instead, the point is to recognise that the EWS processes operate at multiple time and space scales and that individuals are rarely separable from their community contexts, even when they are marginalised within that community.

5.4 Conclusion

All EWSs seem to work perfectly on paper and in presentations, where the ideal situation (what ought to be) can be assumed without problem. Reality proves different, as many factors chip away at the ideal formulation and execution of an EWS. Aside from the social, including political, barriers interfering with successful EWS and creating vulnerabilities, such as for Zimbabwe, the nature of some hazards makes full EWS implementation challenging. The 1998 tsunami in Papua New Guinea suggests that perhaps the only feasible EWS solution is to not live along coastlines where the earthquake-to-inundation time is less than the time required to reach a safe location. If that solution were implemented, then it would devastate the livelihoods and cultures of many coastal and island peoples.

An example of how thoroughly an EWS can become mired in politics is the 6 April 2009 L'Aquila earthquake in Italy which killed over 300 people. Six Italian scientists and an Italian civil servant were tried for manslaughter for the warning information that they disseminated just prior to the main shock. They were convicted in October 2012, although appeals are likely. Much of the media reported the story as finding the defendants guilty for failing to predict and warn about the specific timing and location of the earthquake, a task which is currently impossible. Alexander (2013, p. 9) provides a different view, stating that:

> Science and scientists were not on trial. The hypothesis of culpability being tested in the courts referred to the failure to adopt a precautionary approach in the face of clear indications of impending seismic impact, not failure to predict an earthquake, and this is amply documented in official records.

As further described in Alexander (2010), the EWS failed leading to the trial, but not because of technical faults in the EWS. It failed because of the social process in which those disseminating warnings and information, who later became the defendants, allegedly communicated poor advice based on the hazard information available, thereby exacerbating people's vulnerability.

Parallels are seen for slower moving, creeping hazards, such as climate change. Society's multiple EWSs have given clear technical information for climate change, warning of the foreseeable consequences if no action is taken. The needed actions based on these warnings about climate change are well known and well understood, yet they are not being fully enacted. The problems encountered in dealing with the hazard of climate change are social, not technical.

Where society chooses not to follow the warnings from an EWS, despite foreseeable consequences, do other mechanisms exist which might spur action? The lessons from creeping hazards are poignant in that society often displays little interest in addressing creeping hazards until a threshold has been crossed yielding a crisis (Glantz 1994a, b). In the same way that increased lead time for tornado warning in the USA might be counterproductive for saving lives (Hoekstra et al. 2011), too much lead time for climate change might be discouraging action.

Consequently, a useful notion to explore is different time scales for warnings in order to consider medium warning systems and late warning systems. That does not preclude EWS, but instead indicates that different time scales of warning in combination might contribute towards the social process of appropriate action. The key is not to rely on medium warning or late warning. Otherwise, it might be impossible to take the action needed, as with the 1998 tsunami in Papua New Guinea. Instead, it is about embedding warning systems within society and using different mechanisms, approaches, and information in parallel to support the pursuit of needed actions.

Overall, the main challenge is to focus on an EWS as a social process, overcoming the entrenched view of EWS being mainly technical with those outside a community handing 'expert' information to those in a community. In that sense, the notion of an 'end-to-end EWS' is misleading. It reinforces a top-down operating perspective, by implying that an expert forecaster can produce a forecast and then hand it down (figuratively and literally) to a community eagerly awaiting the hazard information so that they can do exactly what they are told in response. That is, it assumes that an EWS actually has two ends with a linear process moving from one end to the other end.

Table 5.2 'Actually is' and 'Ought to be' for EWS

EWS characteristic	Traditional	Preferred
Elements	Information about a hazard and response actions	Information about a hazard, response actions, preparedness beforehand, long-term education and training about hazards, vulnerabilities, and disasters
Leadership	A separate agency controlling the monitoring and information and then telling people what to do	EWS leaders working with the community so that the elements become part of the community's day-to-day life
Operations	When a hazard manifests, trigger the EWS	The EWS is part of the community's day-to-day life, with activities such as educating about hazards and vulnerabilities, training about disaster risk reduction and disaster response, running drills, gathering baseline data, and further mapping and updating a community's hazards, vulnerabilities, and risks
Focus	One or several specific hazards for specific places	Vulnerability reduction for all hazards

But the end-to-end conceptual model of an EWS does not explicitly allow for feedback from one sector of the EWS, such as those in a community, to other sectors, such as scientists monitoring and interpreting hazard data. Instead, perhaps 'end-to-end-to-end' is needed for an EWS, indicating feedback loops and various pathways from which information comes and to which information flows (see also Anderson 1969).

EWS have existed in some form, as simple as human observation passed down through oral tradition, for millennia—with varying degrees of success. Society is continually being challenged by the vulnerability to hazards which society itself creates and perpetuates. Too often, the fundamental problem is that an EWS for a wide range of hazards and vulnerabilities is not seen as important by decision-makers. Instead, a quick fix focusing on technology for a specific hazard is preferred which assumes that the right information will magically reach the right people who will then magically perform the right actions.

Between the ideal of the perfect EWS and the reality of EWS being social and being subject to social, especially political, interferences and whims, lies 'what could be' (see Table 5.2): an EWS improving on current problems and focusing more on vulnerability without neglecting hazard, even if still far from ideal. With the understanding of EWS as a social process, we take one step closer to saving lives.

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