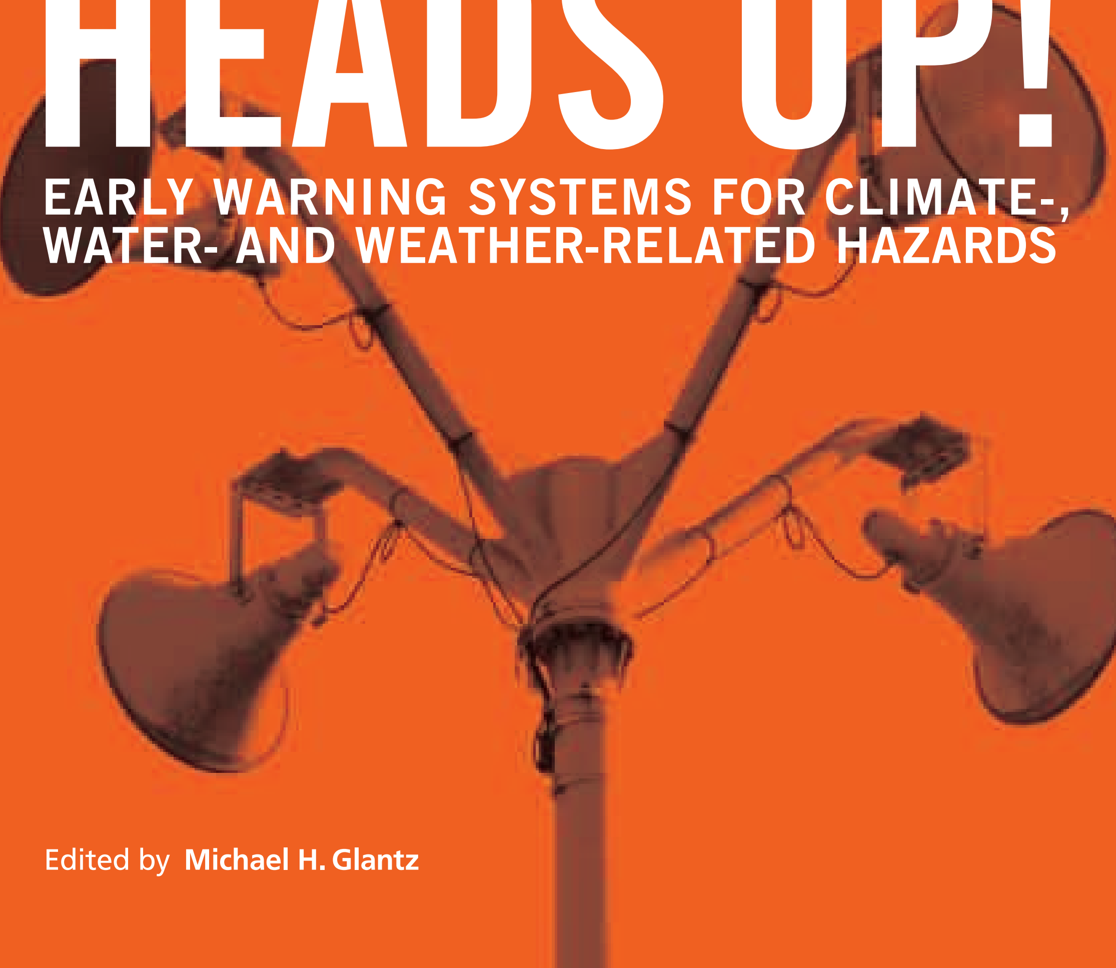
HEADS UP!

EARLY WARNING SYSTEMS FOR CLIMATE-, WATER- AND WEATHER-RELATED HAZARDS



Edited by **Michael H. Glantz**

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Early Warning Systems for Climate-, Water- and Weather-Related Hazards

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Introduction

Interest in early warning

Concerned about impending or likely threats and the problems they may face as a result, all governments, corporations, groups and individuals are interested in early warning in one form or another. At least in theory, the more advanced the warning they are given, the better off they are because they then have ample time to prepare for – at minimum – and hopefully respond effectively to the potential impacts of natural or human-induced threats. As the adage goes in many, if not all, cultures: "To be forewarned is to be forearmed." Yet, as history continues to show, warnings alone are not enough; they must be coupled with a government's willingness and ability to respond.

Many early warning systems (EWSs) exist today to inform the general public, governments and businesses such as insurance companies and grain producers about impending climate-, water- and weather-related hazards, among other natural and human-made threats. The experiences and insights identified around the globe through the use of these EWSs have helped to forearm officials and other decision-makers in various governmental and non-governmental organizations (NGOs) about how to prepare for and communicate effective warnings about future threats. Aside from being the right thing to do – that is, to protect citizens from harm – it is a moral necessity for governments and NGOs to anticipate and respond to threats by protecting their at-risk populations and ecosystems. Sharing experiences also helps to educate the media and the general public about how to interpret warnings and apply them to their own local needs. In other words, possessing information is a source of power, and sharing information empowers

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people by helping them to understand the value, use and limitations of warnings for foreseeable hazards.

Many organizations, from the local to the global, are responsible for early warnings of impending threats to life, limb and property, and the UN system has been given special charge by governments worldwide to foster awareness and progress in the development and effective use of EWSs. Organizations like the WMO, WHO, UNEP, UNDP, UNFAO, UNESCO, IOC, ISDR, WFP, FAO/GIEWS and FEWS-Net, among others, are deeply involved in the various aspects of early warning relevant to their institutional jurisdictions. Humanitarian NGOs are also dependent on EWS output for their effective operations. It is important to keep in mind that there is likely a mix of several formal and informal warning systems focused on similar climate-, water- and weather-related hazards operating at the same time in any given area. Collectively, these systems provide a first defence against a variety of hazards to those in harm's way.

The "Precautionary Principle" as the basis of early warning

In the 1980s the notion of the "Precautionary Principle" began to take hold in international environmental discussions. Based on the view that the scientific uncertainties surrounding an environmental stress should not be used as an excuse for inaction in addressing that stress, the principle supports consideration of the old maxim, "better to be safe now than sorry later", especially if an environmental stress could become critical and have irreversible and costly consequences in time or space. The European Environment Agency, for example, published a collection of studies documenting cases in which the Precautionary Principle was not applied. The publication, entitled *Late Lessons from Early Warnings* (EEA, 2002), gathers information on hazards raised by human economic activities and tracks the use of that information in actions taken to give better protection to the environment and the health of species and ecosystems dependent upon it. In doing so, the EEA (ibid.) "aims to contribute to better and more accessible science-based information and more effective stakeholder participation in the governance of economic activity to help minimize future environmental and health costs and maximize innovation".

Human influence on global climate appears destined, however, to be only the latest global environmental stress (some say "insult") to become, regrettably, just another case of early warnings accompanied by late lessons, though time still remains to prevent, mitigate or adapt to some of climate change's worst causes and impacts. Mindful application of the Precautionary Principle can help avert this swiftly approaching outcome.

What constitutes an early warning system (EWS)?

An early warning system (EWS) is made up of several components and is not well represented as being only the formulation and issuance of a warning. A holistic EWS includes the formulation of the warning, the issuance of the warning, the reception of and response to the warning, and finally feedback to those who developed and issued the warning in the first place. Each component has to be considered in evaluating the system. A weakness in any part of this chain of steps, from warning preparations to responses, can render an early warning system ineffective – an outcome critical to avoid because a system that does not warn will not be taken seriously. Furthermore, an effective EWS must always contain a well-functioning feedback loop, so those responsible for developing and issuing warnings can determine the value of specific types of warnings to at-risk populations and also evaluate the effectiveness of their systems in general (a hindcasting activity).

Because what one person sees as a warning may not be viewed as a warning by others, several basic questions must be addressed while an EWS is being developed or when its effectiveness is being evaluated. Do people agree on what is meant by "early"? What constitutes a "warning", exactly? Who is to be warned? Does everyone (e.g. the government, the media, the public, the military) need to be warned at the same time, in the same way and by the same warning system?

Other important questions arise. How is a warning affected by the reliability and credibility of the sources of information on which it is based? Are there levels or degrees of warning? For instance, is the warning to be like a “go-no go” or “on-off” warning switch (e.g. high alert or no alert), or are there to be levels of warning like traffic lights: green, yellow and red? Or should the levels of warning be graded like those used for weather phenomena such as tornadoes and hurricanes (e.g. a watch, a warning and an alert)?

There are EWSs for just about every conceivable process or hazard of concern to individuals, societies, corporations and governments. They exist on the global scale (e.g. monitoring global warming and stratospheric ozone depletion), at the national level (e.g. regional drought, desertification, famine and large-scale flooding) and at the local level (e.g. infectious disease outbreaks, nutritional changes and flash floods). They are also constantly being created for newly identified threats (e.g. terrorism, West Nile virus, SARS), being revised for changes in existing threats (e.g. food insecurity, invasive species) and being critiqued for shortcomings (just about every system).

For the most part, EWSs are under constant scrutiny, with each half-generation (every 10 years or so) trying to develop the perfect system. Indeed, numerous examples could be cited of truly successful systems that have been credited with the saving of lives and livelihoods and the protection of property. The task, however, is daunting. People and societies have always been in conflict with a varying or changing climate, and existing warning systems are incessantly being challenged by nature in general and by variations in the climate system specifically. Making the task of early warning even more difficult is the fact that societies, let alone ambient environmental conditions, are themselves constantly changing. What this means, of course, is that both the quick-onset event and the slow-onset (“creeping”) process to be warned about are always embedded in a context of other compounding events and processes, and this synergy frequently leads to what are called “complex humanitarian crises”. Complexity, however, should not be used as an excuse for inaction.

Some tools of the early warning trade

A range of tools exist to help provide warnings about events that could threaten the stability of a given society, whether that society is technologically complex or not. For example, meteorological and hydrological services have used advanced technologies in EWSs for decades to warn about all kinds of extreme hydro-meteorological events. In addition, woven into the traditions of indigenous cultures around the world are warning systems for similar events that, though not as technologically advanced, have proven effective for generations in warning local populations about impending threats. Regardless of technology, these warnings – as well as those for a wide range of other events – utilize appropriate tools to mitigate and adapt to threat impacts, improving the likelihood that hazards will be overcome. Four such tools are indigenous knowledge, Geographic Information Systems (GIS), remote sensing and forecast warning terminology.

Indigenous knowledge

Gregory Pierce

Indigenous knowledge comprises the manners and customs that are cultivated intergenerationally by a group of people who have an intricate awareness of their own local environment. Once widely denigrated by Western researchers and colonial agents as the primitive practices of primitive cultures, the importance of indigenous knowledge has been increasingly recognized by researchers over the last decades, especially in terms of its benefits for disaster risk reduction and early warning. Its value specifically derives from its ongoing development as a shared resource that is passed informally from generation to generation, enabling adaptation *within* a community to variations in local environmental conditions; rarely overtly emphasized, indigenous knowledge embodies the traditions that are woven into the very life of a culture evolving through time, the cultural "memory" that ensures its survival from one generation to the next (International Strategy for Disaster Reduction, 2008).

Interestingly, because of its cumulative nature, indigenous knowledge evolved for local survival often also acts as an adaptive mechanism that mitigates the development of what could otherwise prove a creeping threat. In the Turpan Depression of Xinjiang Province in the arid west of China, for example, the *karez* irrigation systems have delivered life for over 2,000 years in one of the most hostile climates on earth. Using mainly hand-tools and an accumulated understanding of the porous rock and slopes of the landscape, traditional groups in this harsh environment maintain thousands of kilometres of underground channels into which snowmelt from the Tianshen Mountains flows, sheltered from the threat of evaporation in up to 50°C desert heat. Continual refinement of indigenous methodologies for constructing and maintaining the systems – development of regularly spaced vertical wells for ventilation, orientation and repair access to the channels, for instance – ensures the provision of stable, gravity-fed outflow and high water quality that has enabled the people in this otherwise barren region to flourish agriculturally for millennia.

Significantly, practices and policies that have over decades and centuries been effective in one community not only encourage participation by members of that community as empowered stakeholders in disaster reduction efforts, but have also been successfully transferred to other communities facing similar threats. Furthermore, development projects planned by outside agencies consistently prove more effective when traditional methods are consulted as valuable complements to project design and implementation. Ironically, the informal, once-derided means by which indigenous knowledge is passed on are today considered by more formally trained, technologically inclined disaster planners as a valuable paradigm for disaster education programmes around the world (ibid.).

Indigenous knowledge is now recognized as an essential tool in developing mitigation and adaptation strategies for the threats of the twenty-first century. In fact, governments, the United Nations and NGOs around the world are working cooperatively with indigenous groups to understand and incorporate many aspects of local knowledge into the development of wider-ranging disaster mitigation and early warning systems. Where practical, these agencies are also providing assistance to indigenous groups by informing them about the future threats they will face, such as climate change, and by encouraging them to integrate appropriate technologies – not to replace but to reinforce traditional methods and customs – to mitigate the impacts of such new threats for which they could not have a cultural "memory".

Geographic Information Systems (GIS)

Jennifer Boehnert

Geographic Information Systems (GIS) is a technology designed to collect, store, analyse and display data regarding real-world objects (e.g. rivers, cities, etc.) and events (e.g. hurricanes, droughts, etc.). The "G" in GIS is the unique aspect of this technology; it represents the association of geographic data that can be located on the earth's surface (spatial data) with data that contain descriptive information about these real-world objects and events (attribute data). Through visualization, a comprehensive understanding of these events, along with event-specific impacts, threats and outcomes, can be achieved. The ability to overlay disparate datasets with different themes is another important aspect of GIS technology (fig. 1.1). For example, GIS can be used to ask questions such as which areas are below sea level, have a population density per square kilometre greater than 900 and are susceptible to frequent flooding. These types of questions – and their answers – can greatly improve our understanding of real-world events and their effects. But although computers can help to visualize and analyse the data, by themselves they cannot solve complex problems; human intervention and interpretation are needed. The

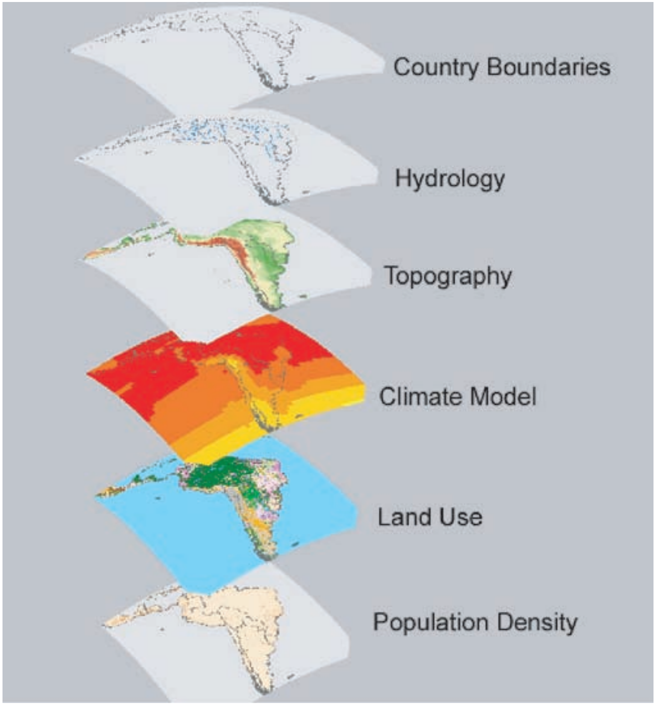

Figure 1.1 A GIS overlay combining several different physical and political features
Source: J. Boehnert.

human component in GIS, along with data analysis and visualization, makes GIS an important tool for decision-making and monitoring natural hazards.

GIS can be used to make a baseline assessment of the vulnerability of a population or evaluate the risk to a geographic region resulting from a particular hazard. Vulnerability mapping can be used to facilitate the development of an emergency plan and better identify preparedness and response actions in case of a hazard. For example, rainfall and wind thresholds can be monitored using GIS technology. During the monitoring phase, GIS can be used to acquire, fuse and analyse a large amount of real-time weather data quickly. Once data are mapped in a GIS, they can be provided as critical guidance to decision-makers, which can aid the mitigation, planning, response and recovery processes. Furthermore, if predetermined thresholds of risk levels are approached, the GIS system can be used to alert emergency managers and first responders to the threat and quickly identify vulnerable populations.

GIS is already being employed in several EWSs around the world. A good example is the UN Food and Agriculture Organization's Global Information and Early Warning System (FAO/GIEWS). GIEWS has developed a suite of software tools called the GIEWS Workstation, a one-stop, web-based system providing maps, tables, charts and documents on food-security-related issues. GIS is a central part of GIEWS's web workstation, providing access to information based on spatial locations as well as spatially related information such as real-time satellite images and base data. GIEWS Workstation facilitates access to food-security-related information for monitoring food supply and demand in virtually all countries in the world.

Another illustration of the use of GIS is the Mapping Malaria Risk in Africa (MARA/ARMA) initiative. This is a collaborative project that collects data from Africa-based regional centres to map the risk of malaria on the continent. GIS is used extensively in this project to collect and store data as well as to generate maps to illustrate areas at risk. Again, this critical information is disseminated to decision-makers in an effort to ensure an effective response to potential outbreaks. It is quickly becoming the pre-eminent data resource for malaria risk mapping in Africa (MARA, 2004).

With enhanced interplay between data formats and improved access to data through the Internet, GIS can become an integral part of just about any early warning system.

Remote sensing
Stefanie Herrmann

Numerous satellites (e.g. NOAA AVHRR, Terra MODIS, Meteosat, GOES) with sensors operating in different portions of the electromagnetic spectrum are detecting energy reflected or emitted globally from the earth's surface and atmosphere day and night. Acquiring such information about the earth's surface from space by making use of the interactions between electromagnetic energy, the atmosphere and the earth's surface is called remote sensing, and it has been an important source of early warning information for several decades. It also constitutes a major input into GIS.

Remote sensing data acquired at high temporal frequency have a great potential for real-time monitoring of cloud movements, sea and land surface temperatures and vegetation conditions, producing data with multiple applications in early warning. With these data, for example, the formation and paths of tropical storms, winter storms and sandstorms can be monitored, and specific warnings about location, time and intensity of these high-impact weather events can be issued hours ahead of actual impact. Early warning of slow-onset phenomena, such as droughts and floods, also benefits from remote sensing. For instance, the long-term monitoring of sea surface temperatures, which in turn affect large-scale atmospheric dynamics and precipitation as well as vegetation conditions, is used to assess drought and flood hazards. Remotely sensed vegetation monitoring coupled with weather predictions form the basis for fire hazard warnings. Furthermore, early warning systems for climate-linked disease outbreaks, such as cholera and malaria, use remotely sensed data to infer the presence of disease-causing agents by monitoring water temperatures and nutrient concentrations, which have been found to correlate with disease outbreaks. Physical and biological changes in oceans are also monitored from space.

The vantage point of space, particularly when combined with the results of field-based vulnerability assessments in a GIS, has proven remote sensing to be a valuable tool for the early warning and disaster management communities, and is increasingly being applied by governments and non-governmental organizations to decrease the impacts of climate-, water- and weather-related hazards.

Forecast warning terminology

All meteorological and hydrological services, as well as many climate-related organizations, have their own specific terminology for warning their constituents (e.g. governments, corporations, private citizens) about climate-, water- and weather-related hazards. As an example, the US National Weather Service (NWS) has developed terminology for weather- and climate-related warnings.

- *Outlook:* The potential for a hazard exists, though the exact timing and severity are uncertain.

- *Watch:* Conditions are favourable for the occurrence (development or movement) of a hazard. The public should stay alert.

- *Warning:* A hazardous event is occurring or is imminent. The public should take immediate protective action.

- *Advisory:* An event that is occurring or imminent is less severe than one that merits a warning. It may cause inconvenience, but it is not expected to be life- or property-threatening if normal precautions are taken.

- *Alert:* The highest level in the warning system, issued when a hazard is sure to occur.

- *Statement:* Detailed follow-up information to warnings, advisories, watches and outlooks is provided.

Readers must keep in mind that for the most part early warning systems differ from country to country. Some governments consider production and issuance of a warning as a stand-alone activity, leaving responsibility for interpretation and response to other agencies. Others look at EWSs in a more holistic way, believing they encompass production and issuance of warnings plus responses to impacts.

Early warning terminology can also vary from country to country, and from one type of hazard to another even within the same country. The entries in this book are drawn from various countries; individual readers can compare these examples to their own society's threat terminologies.

EWS quick facts

- EWSs are politically sensitive; they are not politically neutral.
- One EWS does not fit the needs of all users; one EWS does not fit all hazards.
- People debate the meaning of each word in EWS (early – warning – system).
- Early warning is a high-visibility, risky and thankless job.
- "Success has many fathers. Failure is an orphan."
- People tend to recall failed warnings more often than successful ones.

- EWSs are integral to sustainable development.
- People have different views about the structure and function of an EWS.
    - EWS as a technical unit issuing only quantitatively based warnings.
    - EWS as a holistic method including warning, communication and response.
- Not all governments or EWSs want transparency in early warning processes.
- No agreement exists on how best to express "likelihood" or "probability".
- There are unknowable and knowable surprises.
- There should be degrees of warnings:
    - Outlook
    - Watch (earliest warning)
    - Warning (earlier warning)
    - Alert (actual warning)
    - Hotspot (target of threat identified)
    - Flashpoint (threat is imminent; little lead-time exists).

Threats: The perils that compel early warning

Every society in the world has its own unique set of threats about which to be concerned and for which to prepare. Some of these threats are natural, while others are directly or indirectly human made. Some can be well prepared for, while others cannot be. Regardless, threats of one kind or another will always exist. While we cannot necessarily eradicate all of them, we can become better aware of their likelihood and potential impacts. For most of these threats, both perceived and real, an early warning apparatus, however formal or informal, has been established. Although some of these warnings may not be labelled as "warnings", they are, in essence, warnings based on forecasts, projections, scenarios and trends as a result of tracking a selected, explicitly identified set of indicators.

In the end, every society, whether rich or poor, industrial or agrarian, democratic or totalitarian, capitalist or socialist, must determine which threats are credible and based on reliable indicators (qualitative as well as quantitative) and which ones are based on less reliable factors, such as unsubstantiated rumours. The difficulty is providing a reliable warning of a potential threat with enough lead-time for recipients of the warning to take appropriate evasive action. In many respects, consequently, the problem with early warning boils down to the common difficulty of perception versus reality.

The perception of the role of EWSs

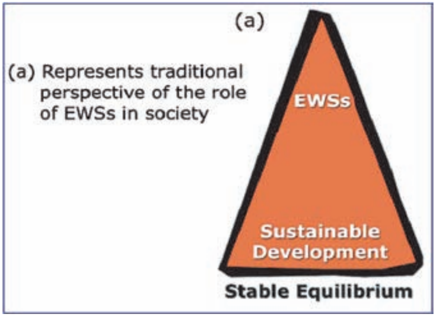

Figure 1.2 Traditional perspective of the role of EWSs in society

Figure 1.2 is a graphic representation of how governments tend to look at EWSs of all kinds, including those for climate, water and weather. The pyramid suggests that governments view societies as stable entities resting on firm foundations.

At its apex is a proverbial “searchlight” that clearly illuminates the perimeter around the base of the pyramid. When a troubling situation enters the illuminated area near the base, a government (in theory at least) initiates a response mechanism to resolve the problem and bring life back to normal. This perception of the role of EWSs in society is, however, readily challenged.

Recent natural and human-made events do not support this pyramid view of societal stability and the role of EWSs. In the United States, for example, the 9/11 terrorist attacks on the Twin Towers and the Pentagon (2001) and the impacts of Hurricane Katrina (August 2005) both highlight how the stability of a society can be shaken by poor implementation of or ineffective early warning systems. Similar examples of destabilizing events occurring because of poor foresight about the importance of effective EWSs can be found in many countries.

Clearly, societies need to rethink how they view, maintain and use their early warning systems if they want to ensure that these mechanisms are effective when needed.

The reality of the role of EWSs

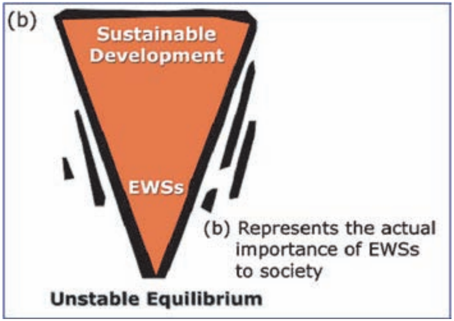

Figure 1.3 Actual importance of EWSs to society

In fact, the reality of EWSs in society can be portrayed graphically as a pyramid resting on its apex in a position of unstable equilibrium, as in figure 1.3. Societies and the governments that lead them are actually dependent on a wide array of early warning systems focused not only on terrorism but also on economics, politics, natural resource use, environmental changes and natural hazards. The better and more effective these EWSs, the flatter the apex becomes upon which the pyramid rests. While societies and governments can never be completely stable, improved warning systems go a long way to increasing social stability.

The situation unfailingly returns to the problem of sustainability. Immediately after a crisis, an EWS receives a lot of attention. As time passes in the absence of similar crises, however, interest in and funding for the EWS sharply decline. But EWSs are much more important than governments often realize; the reality, as illustrated in figure 1.3, is that social, political and economic stability depend on them. Without effective EWSs, a society is highly vulnerable to natural and human-induced threats. At a general level, all societies are aware of this. In practice, however, intervening factors detract from the efficiency of EWSs, leaving societies increasingly vulnerable to the adverse impacts of numerous kinds of hazards. Ultimately, one of the central goals of a government should be to flatten the apex of the inverted pyramid that is its society by improving moral and financial support for its early warning systems in order to build more stability into its social, political and economic systems, which always exist in tenuous equilibrium.

Surprises

Unstable equilibrium obviously does not bode well for a goal of stability. The problem, of course, arises from the element of surprise – the fact that not every possible circumstance can be adequately planned for. Indeed, central to the very definition of surprise is the notion of the unexpected; yet many people use the word “surprise” independently of this notion. For example, at some time or other everyone has uttered such expressions as “I was semi-surprised”, “almost surprised”, “hardly surprised”, “a little surprised”, “somewhat surprised”, “sort of surprised” and so forth.

The truth is that there are “knowable surprises”, even though this expression seems contradictory. Of course, if you consider only denotations, you can in no way know that a surprise is coming. But there are surprises that resonate beyond the dictionary’s definition and are, essentially, knowable, as in the example of hurricanes: although the timing, magnitude and exact landfall of a specific event may be unknown, the fact that certain areas are prone to hurricanes is known. Despite the obstacles presented by these unknowns, that the knowable component exists should facilitate the development and implementation of mitigation strategies to counter the threat. Indeed, these knowable components of surprises are why governments and donors must take early warning activities much more seriously than they have in the past.

It is not enough, however, for a society to have an accurate forecast of an impending hazard: a good forecast system is only one part of a broader early warning system in which effective communication of the warning and response mechanisms are integral parts. Having a poorly supported early warning system is also not good enough. If it has only low levels of moral and/or financial support, a system could become ineffective in delivering appropriate warnings to those in need because it could fail to provide them with enough time to respond proactively to those warnings.

Effective early warning systems, on the other hand, can empower governments in ways that help them in the face of climate-, water- and weather-related hazards to protect their citizens as well as their political stability. Several examples exist where poor responses to forecasts and impacts of climate-, water- and weather-related hazards have contributed to the downfall of governments – as was the case during the 1968–1973 drought in the West African Sahel when three governments were overthrown by drought-related military coups. In 1974 the Ethio-

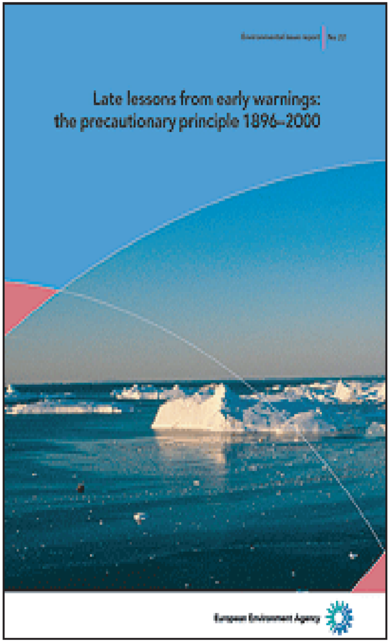

Figure 1.4 Cover of EEA publication, *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000*

pian government was also overthrown, with drought again serving as the justification by the military junta.

Those involved in environmental monitoring activities have at one time or another been faced with attempts to reduce their funding, especially if the hazard they are monitoring has not manifested itself for some time. To minimize unexpected surprises, however, this “benign neglect” of EWSs by governments must be made explicit and avoided.

The future has been arriving earlier than predicted; take global warming, for example

With each passing decade since the 1970s, it seems that more and more of the signs scientists have warned us about related to the gradual warming of the earth’s atmosphere have been observed. Many of these signs are emerging far more quickly than originally predicted, yielding an increasingly palpable sense of urgency for response planning. For example, sea level continues to rise; 96 per cent of the world’s glaciers are receding; warm climate ecosystems are moving upslope to higher altitudes and into previously cooler climates and latitudes; and exotic species and disease vectors are appearing in new locations poleward, adjusting to warmer winters and hotter summers. Droughts seem to be recurring with greater frequency and intensity in some drought-prone locations, and floods are doing the same in flood-prone locations. Additionally, Arctic sea ice has been disappearing at an increased rate, drawing nearer and nearer every year to a dangerous tipping point beyond which an ice-free Arctic will no longer be avoidable.

Many of these changes are taking place earlier than expected, at rates faster than expected and in places where they were often unexpected. Furthermore, we are starting to see stronger storms, some of which are now being labelled “superstorms”. In fact, we are witnessing the appearance of “seasons of superstorms”.

While many of the computer-model-based climate change scenarios yield the foreseeable consequences of global warming out to the year 2050, 2070 or even 2100, we are now already witnessing in different parts of the globe some effects scientists had expected to take place in the distant future. Coral reefs are dying worldwide; permafrost is melting; each new year seems to be ranked in the hottest 10 years on record; tropical storms in the Atlantic, Pacific and Indian Oceans are increasing in frequency and intensity; and so forth. These are changes that had been suggested verbally and in print for several decades, but now they are no longer speculative. Now, they are real.

Compounding the physical and biological changes accompanying global warming (all observers admit that the climate has warmed by about 0.7°C since the early 1900s) are demographic changes, such as in population growth and migration, land transformation and land-use pattern shifts, increasing exploitation of a wide range of natural resources and intensifying water and food shortages. In addition there has been a growing trend worldwide of population movement towards the coastal areas, which are going to be increasingly at risk from tropical storms, storm surges and sea-level rise. More than ever, timely warnings for the entire range of potential threats – old, new and intensified – are essential in response to the changing dynamics of the environment.

Strengths, Weaknesses, Opportunities and Constraints assessment

The UN Development Programme (UNDP) uses an assessment technique called SWOC (Strengths, Weaknesses, Opportunities and Constraints) to evaluate various programmes and activities. The following paragraphs apply SWOC to early warning systems in general, especially emphasizing early warnings related to atmospheric processes such as droughts, floods, frosts, fires, heat and infectious disease outbreaks. Important to keep in mind is that each weakness or constraint can also be viewed both as an opportunity for future improvement and as an evolving challenge to society.

Strengths

People want to know what the future has in store for themselves, their families and their societies. The same is true for every government. A glimpse into the future, therefore, no matter how reliable (or unreliable), is always viewed as having some value to someone, so the strength of an early warning about any threat that might impinge on routines or livelihoods or the workings of government is seen as having value. Value, however, is a loaded term, because what one person values another may not; what one government values, another may not.

Early warning implies that there will be "ample time" to react to the information conveyed by the warning. Ample time refers to lead-time and is a relative term, dependent on the hazard or concern. An early warning several months in advance of the development of an El Niño episode in the tropical Pacific can provide many countries with several months of usable lead-time. A tornado warning, on the other hand, may be issued only a matter of a few minutes or hours ahead of a tornado's impact. Both, however, can provide enough lead-time to take evasive, protective action.

Nevertheless, there are time constraints on warnings. To hear about a flash flood as the water is rushing at your doorstep does not provide ample time to act – the warning is too late to be usable. Also not very useful is an early warning that is given too far in advance of the impact of what is being warned about; for example, if you are living in a region you know is prone to flash flooding, can that knowledge be considered an early warning? In both of these flood scenarios, the information provided might be of some use, but does not, by itself, maximize the potential benefits for those being warned. The former example may allow you to save some possessions and even your life; the latter, on the other hand, would only enable you to protect yourself against a low-probability, worst-case, flash-flood scenario.

The bottom line about the value (strength) of early warning systems is that governments, the media and the general public, as well as those most at risk to climate-related or other hazards of concern, can be warned to take appropriate action. They must only be receptive to being warned.

Weaknesses

In theory and on paper, early warning systems function quite efficiently. In reality, however, they seldom work smoothly. Despite the best efforts of individuals, agencies and governments, neither nature nor the climate follows a set pattern or a government's best hopes for their good behaviour. In planning for hazards, therefore, as American ecologist Barry Commoner once said of the natural environment, "You can't change just one thing." This is especially true as far as human interactions with climate systems are concerned, where demographic changes (population shifts as well as increasing affluence or increasing poverty) over time alter the impacts on societies and ecosystems of constantly varying and changing atmospheric behaviour.

Thus other factors beyond the issuance of a warning itself – such as the ability of those at risk or agencies responsible for them to receive and understand the warning and the phenomenon being warned about, political access of at-risk populations, vulnerability of communications and transportation infrastructures to hazard impacts, or even the desire or capacity of a government to take appropriate action – influence the actual, as opposed to the hypothetical, value of an EWS.

Needless to say, there are weaknesses inherent in early warning systems, too. For example, usually no single indicator can provide the optimal lead-time for a warning. Different groups with different perspectives and interests are likely to have chosen their own sets of indicators for local hazards that they have had to face in their lifetimes. How then are reviews and assessments of all possible indicators to be taken from all the various sources in order to create a reliable, credible and timely warning of an impending threat or hazard?

Despite such questions, early warning systems do require set structures as well as explicit functions (or purposes). In reality, they are often bureaucratic units embedded within larger bureaucratic units which are themselves embedded within even larger bureaucratic units. Considering this reality, EWSs require flexibility because reporting procedures across these units can be designed either to accelerate or to inhibit the flow of warning information. Unfortunately, bureaucracies are often run by people who cannot help but have vested interests in their organizational units, if not their work; these people collect information selectively, focusing on their unit's specific area of jurisdiction or the realm of their own experience or expertise. This is normal human behaviour. As a consequence, however, bureaucratic jurisdictions often become obstacles to the quick issuance of (or the response to) an early warning.

Individual perceptions about the strength or weakness of certain indicators in terms of predictive power can also hinder a quick response to an early warning. For example, in the late 1980s in Ethiopia, even though the country's National Meteorological Agency (NMA) had issued warnings of the likelihood of meteorological drought, the Minister of Agriculture, noting that *his ministry's* forecasters had not come up with the same drought scenario, challenged those forecasts instead of treating them as early warnings. Because chronic hunger had already become a fact of life and food assistance had to be requested and brought into the country, who was correct is difficult to determine. What is important is that the meteorological service did provide the government with a "heads up" on a drought, a food crisis and the potential for famine, and, despite the agriculture minister's challenge, the government did eventually have to seek humanitarian food aid.

Many affected governments and donor agencies want to be the first to receive a warning, often in private, either to avoid causing panic among the public or for other socio-economic or political reasons. They finance the development and maintenance of early warning activities because they do not want to be surprised by the sudden emergence of a threat about which they should and could have been forewarned.

In the end, information is power, and information received by one special-interest group, a ministry, for example, ahead of others can be politically very rewarding. This truism, however, suggests another weakness in early warning systems, because communities or groups at risk are ultimately the ones that should be warned as soon as possible to provide them with as much lead-time as necessary to mitigate the effects of a hazard; however, at-risk people often do not have the resources needed to cope with a forecasted hazard. Consequently, governments, which possess more resources to respond to foreseeable hazards than individuals or groups, often need to be informed first.

Opportunities

Opportunities for developing new or improving existing EWSs are, in fact, limitless. Indeed, many proverbs exist in societies worldwide about being precautionary, so there is little need to sell a precautionary level of awareness about EWSs to governments; however, problems often emerge when finances are needed, especially for maintaining an environmental monitoring capability. This reality becomes increasingly apparent as EWSs are considered for phenomena that are infrequent or rare.

New technologies for and new approaches to early warning have provided new opportunities for reducing the risk of climate-, water- and weather-related problems. Such opportunities are provided by improved scientific understanding of the hazards of concern; by new technologies for detection purposes; by better identification and targeting of at-risk populations; by improved understanding of second-order, hazard-related impacts; and by a seamless transfer of information to those who are in positions to respond to warnings.

Communication advancements related to the issuance of warnings and the targeting of those warnings to relevant agencies and at-risk populations have also greatly improved. The Internet, satellite radios and mobile phones now serve as vehicles for warning dissemination. Satellites, for example, provide images with improved resolution, and Google Earth on the Internet provides images of impacted regions and localities in real time, enabling those with the requisite electronic devices (e.g. radio, TV, computer, PDA, wireless phone) to monitor the progression of a hazard.

Lastly, the globalization of communication and education has worked wonders by bringing stories of both successes and failures to the attention of those facing similar risks and threats, whether they happen to be in urban centres or remote areas, in other parts of the globe.

Constraints

Not everyone in a known at-risk location has equal access to early warnings, regardless of the means used by those responsible for early warning systems to broadcast them.

For example, even though connectivity to EWS output is crucial to reducing impacts, at-risk populations are not always connected to various types of electronic media. Because of this reality, other means of delivery need to be made routinely available, such as the use of satellite radio (e.g. RANET), mobile phones and public sirens. Language differences are yet another potential constraint. There is a need to make sure that warnings are provided in appropriate languages – foreign, non-scientific and even non-verbal. No single communications medium, however, will ever reach an entire at-risk population.

In the absence of a hazard over an extended period of time (which varies by threat, country or group), a tendency exists to downplay the continued need to finance the formal structures of the early warning systems associated with that hazard. The costs are often viewed as not worthwhile, given the relative infrequency of the hazard. What comes to mind is the TV commercial about an appliance repair man who sits around day after day, bored as could be, waiting for a call to repair an appliance that has been manufactured so well that it never needs to be repaired. Eventually, however, he will receive the call; similarly, an EWS will eventually prove invaluable when a threat inevitably does arise.

Another problem occurs when a warning has been issued but the hazard fails to occur, or, on the other hand, when hazards prove challenging to predict and warn about because they are either quick onset or of varying intensities. As a result, belief in the effectiveness of early warning systems is likely to decrease. Such a reaction is, however, inappropriate. Any forecast of a potential hazard has a possibility of being incorrect (the hazard could weaken or change location, or its impacts might not be as severe as expected because appropriate actions were taken to mitigate them, among other possible reasons).

As problematic as is the issuance of infrequent early warnings in proportion to the frequency of a certain hazard's likely occurrence, the problem of issuing warnings too often must also be considered. This scenario can generate the "cry wolf" problem when a real emergency arises and a warning is not taken seriously (fig. 1.5). For example, once when the US Department of Homeland Security in Washington, DC, elevated the terror alert from Yellow to Orange, a local official in the US state of Arizona referred to the warning as “Orange-lite”, suggesting that one warning for the whole country was inappropriate as the likelihood of a terrorist attack in his district was considerably lower than it would be for a major urban area in, say, the eastern United States.

Figure 1.5 The dangers of crying “wolf”

Furthermore, warnings, forecasts and projections are constantly being issued about this or that hazard to various parts of society. This profusion of forecasts and warnings, issued by a range of institutions, agencies and groups and often suggesting conflicting levels of threat, can confuse the public and the media and decrease the likelihood of either taking a warning seriously. Such a situation also makes it difficult to know who to rely on for early warning of an impending climate-, water- or weather-related threat. Because preventing these erroneous or misinformed pronouncements about threats is not possible in most cases, however, a consistent approach must be developed to inform the public about the reliability of specific forecasts issued for the same threat. At the same time, as broad an audience as possible must be empowered to make informed decisions when faced with the anticipated consequences of possible threats, even if those threats sometimes fail to materialize.

Accordingly, this book is intended as a first step in making early warnings of potential threats to the environment and to society more credible, reliable, usable and useful to a broad audience. In realizing this intention, the following chapters gather together for the first time essential material from across the sizeable but largely scattered body of academic work that exists on early warning systems, presenting significant concepts from the field in language accessible to readers from all backgrounds, from students to community organizers to activists to government officials. In this way, it is hoped that this book advances the vital idea of “usable science” in the twenty-first century.

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