CHAPTER 1

Coping with Environmental Hazard

Risk assessment is a small but essential part of the process by which individuals and societies cope with environmental hazard. Viewed as a system, *environment* and *society* are linked by a chain of *events*, *consequences* and *coping actions* (Figure 1.1). Understanding of the system may begin with any of these elements, and the various disciplines and professions tend to have more expert knowledge or interest in one or another element. At the same time, such graphic and conceptual devices are inadequate. They oversimplify and atomize organic relationships and make static the dynamic. For while it is helpful to distinguish between a society (or an individual) and the environment that surrounds it, environment and society are only meaningful concepts in terms of each other and the related environmental hazard.

1.1 ENVIRONMENT AND SOCIETY

Most events with hazard potential occurring in nature, technology or society are in themselves neutral (excepting the intentional). They become hazardous only in their harmful interaction with human populations, activities, and wealth and with the environments that humans value and need.

By illustration, consider so-called natural hazards. If people are absent from an area in which an extreme natural event occurs, then they are not usually affected by it. Insofar as people are present: the density and distribution of population, the style and level of economy, the shape, size and character of buildings, the patterns of production, consumption and leisure, affect in significant ways the consequences of the event. Natural events are indeed natural, but hazards – the threat potential for humankind and its works – are by definition human phenomena. If Bishop Berkeley's dictum is extended, it can be said that not only is there no sound when the tree falls unwitnessed in the forest, there is also no danger from falling trees.

In the interaction between environment and society there are many transactions, some of which are clearly beneficial to society and environment, a few clearly harmful, and many with elements of both benefit and harm. Such elements, be they of nature, technology or society, cannot be easily separated into either beneficial or harmful categories, for it is the human search for the beneficial that often results in the harmful. In nature, it is a matter of degree to distinguish the flood from the rains that water the plants, the storm from the winds that bring moisture. In the making and the using of things, we create threat as well – buildings can burn, cars can hit, and drugs can poison. Similarly, in joining with others in complex social relationships, people become vulnerable to violence from war and crime, to illness

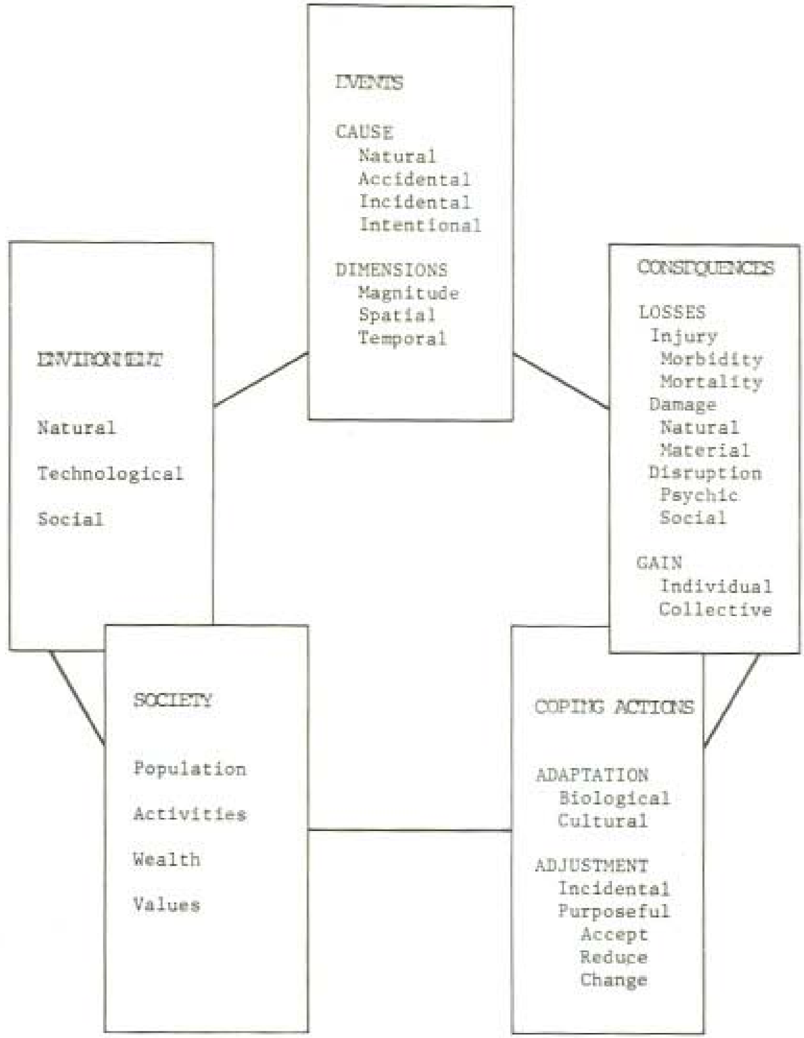

Figure 1.1 Coping with environmental hazard

from propinquity and social mixing, or to deprivation from unemployment and inflation.

1.2 EVENTS

Embedded in many languages and laws is the distinction between the Act of God (or nature) and the Act of Man. The Acts of Man, in turn, can be seen as either intentional (with good or bad intentions) or accidents (with or without imputed negligence). The accidental, a chance failure or unintended happening, can be further distinguished from the incidental, an event that occurs neither with failure nor intention, but indirectly in the course of the pursuit of other ends. Historically, yesterday's Act of God frequently becomes today's Act of Man as more and more control and responsibility for environment is achieved or assumed. And for many cultures, the Act of God or the gods may not be accidental; rather it may be more intentional than Acts of Man. Thus, while these distinctions may have meaning in any given society at a particular time, universal meaning for these categories appears unlikely.

Related to cause is the sequence of events. While ultimate cause may be with God or man, the immediate cause may be simply another event. To use an example suggested by Slovic et al. (1976), a car may fail to start because of failure of the battery, starting system, fuel system, or ignition system. The battery might fail because of loose terminals or a weak battery charge. A weak battery charge could occur because of lights left on, cold weather, or defective generator. Lights might be turned on during the day because of rain, fog, a tunnel, or accidental switching. An analysis of such events in this manner takes on a branching, tree-like structure (fault-tree, decision-tree, pathway analysis), and the starting events may be called initiating events. Both logic and imagination constrained by practical consideration determine how fine the branching structure and how elaborate the sequence of events should be.

With so many possibilities, therefore, the definition of the key events or causes is difficult even within a common model of causality. For different models of causality (as found in many societies and cultures), the events perceived as critical may vary widely. And whatever the model of causality, there may be events that defy structural analysis. Such 'fuzzy' events seemingly arise from the cumulative effects of many small contributory factors, as with some lifestyle changes that are found threatening, or by the little understood synergy of multiple factors, as in certain human metabolic processes.

Events not only have cause, they have dimension as well. Since it may be helpful to separate events from their consequences, there is need for ways to describe events independent of their consequences. One set of dimensions describes the size and the spatial and temporal distributions of events with hazard potential. Thus, independent of consequences, the quality of water can be described in terms of the number of colonies of *E. coli*, earthquake occurrence in magnitude of energy, nuclear power hazard in the venting of fission products, and climatic change by the areal extent of the effect.

For natural hazards, size, space and time dimensions seem to overlap, forming a continuum between the pervasive and the intensive. *Intensive* hazard events are characteristically small in areal extent, intense in impact, of brief duration, sudden onset and poor predictability. *Pervasive* hazard events are widespread in extent, have a diffuse impact, a long duration, gradual onset and can be predicted more accurately.

The sets of natural hazard events which fall most easily into the intensive class are: earthquakes, tornadoes, landslides, hail, volcanoes and avalanches; and into the pervasive class: drought, fog, heat waves, excessive moisture and snow. Other hazards are less susceptible to grouping, and examples can be found at both ends of the spectrum, as in the case of floods. These might be described as *compound* hazard events, displaying mixed characteristics. Some flash floods are close to intensive events, while others – the great riverine and deltaic floods – are pervasive. Other compound hazards such as tropical cyclones, extreme winds, blizzards, tsunamis and sand and dust storms have both intensive and pervasive characteristics.

Among natural hazards, the pervasive-intensive continuum provides a way in which comparisons between hazards can be made. A comparable typology of the events of the technological and social environments is yet to be developed, but it seems likely that similar characteristics will be found. The distinction made in medicine between acute and chronic disease, between rapid onset-short duration and slow onset-long duration suggests such similarity. And some technological hazard events have characteristics similar to natural ones, those of air pollution and drought being good examples.

1.3 CONSEQUENCES

The consequences of hazardous events include: threats to person, morbidity and mortality; damage to activities and wealth both natural and man-made; disruption to psychic and social activities and well-being; and, although often forgotten, the antithesis of the foregoing – instances of individual and collective gain.

The major consequence of hazard to individual people is death. In industrialized countries, the environment contributes little directly to what is primarily the burden of age and disease. Out of slightly less than two million Americans who died in each of recent years, perhaps 500 died as a consequence of natural hazard, 50,000 from

TABLE 1.1 An Environmental Matrix (Part 1): Events and Consequences

Environmental problems by order of gravity	Causative factors 1. size of population 2. concentration of population 3. per capita income level 4. consumption pattern 5. technology	Character of insult 1. temporary insult 2. cumulative insult 3. reversible damage 4. permanent damage (human time scale) 5. synergistic potential	Problem threshold 1. continuing 2. now or soon 3. one generation 4. more than one one generation	Area affected 1. local 2. regional 3. national 4. international 5. global
Amenity considerations				
Litter	4, 3	1, 2	1	1, 2
Noise	2, 5	1	1	1
Odor	5	1	1	1
Air, visibility aspects	2, 5, 4	1	1	1, 2
Water quality, recreational aspects	5, 2, 1	1, 2, 3, 5	1	1, 2, 4
City, aesthetic aspects	4, 5	N	1	1
City, convenience and efficiency aspects	2, 4	3	1, 2	1
Country, aesthetic aspects	5, 4, 1	2, 4	1, 2	1, 2, 3
Access to country and nature	4	2, 3	1, 2	1, 2

TABLE 1.1 (*continued*)

Environmental problems by order of gravity	Causative factors 1. size of population 2. concentration of population 3. per capita income level 4. consumption pattern 5. technology	Character of insult 1. temporary insult 2. cumulative insult 3. reversible damage 4. permanent damage (human time scale) 5. synergistic potential	Problem threshold 1. continuing 2. now or soon 3. one generation 4. more than one one generation	Area affected 1. local 2. regional 3. national 4. international 5. global
Human health effects				
Air pollution-combustion products	5, 4, 2, 3	1, 3, 5	1, 2, 3	1, 2
Water pollution:				
Pathogens	2, 5	1, 3	2, 3	1, 2, 4
Nitrates	5	2, 3	2, 3	1, 2
Industrial chemicals	5	All	2, 3	1, 2, 4
Pesticides (via food chain	5, 1, 3	2, 3	3	2, 4, 5
Radioactivity	5, 3	2, 4	3	1, 2
Heavy metals	5	2, 4	All	1, 2, 4
Human genetic and reproductive effects				
Radioactivity	5, 3	4	3, 4	3, 5
Pesticides	5, 1, 3	4	N	3
Industrial chemicals	5	4	2, 3, 4	1, 2, 3
Effects on ecological system and the earth's life supportive capacity				
Human occupancy of biospace	5, 1, 3, 4	2, 4, 5	All	3, 5
Ocean threats:				
Pesticides	5	2, 4, 5	3	5
Oil	3, 4	3, 5	3	5
Other chemicals	5	2, 4	3, 4	5
Erosion	5, 1, 3	2, 4	1, 4	1, 2, 5
Fertilizers and damage to mineral cycling	5	3	4	1, 5
CO_2, albedo, and climate	5, 1, 3	2, 5	4	5
Heat rejection:				
Local aspect	5, 2	1, 5	2, 3	2, 4
Global aspect	3, 1	3, 5	4	5

N = none, unknown, uncertain, not applicable, negligible.
Adapted from: Brubaker, 1972, pp. 186–189.

the violence of others (war and crime) and of self (suicide), and 100,000 from accidents with the built and machine environments. More difficult to express quantitatively is the effect of environmental events on disease rates: natural and man-made radiation of birth abnormalities and malignancies; the pollutants of the technological environment on respiratory diseases and cancer; the hazards of poverty and poor housing on childhood mortality; or the pace of society on cardio-vascular disease. In developing countries causes of death may be reversed; as many may have died from natural hazard in Bangladesh as from heart trouble in the United States.

The monetary value of damage is considerable as well. In the United States, damage and preventive measures for natural hazard cost an estimated $10 billion per year; for air and water pollution $30 billion. The wage and health costs of accidents are $25 billion. The loss from fire is $2.5 billion. Psychic and social disruption are widely assumed but poorly documented. Individual and collective gains range from the shopkeeper who temporarily profits from his competitor's flood or fire to the sense of well-being and solidarity some communities and nations evidence when performing well in the face of a disaster.

Brubaker (1972) has devised an environmental matrix (see Table 1.1) which combines a number of the dimensions of events and consequences described herein,

TABLE 1.2 Hierarchy of Risk Consequences

1. Premature Death (Avoidance)
   a. Catastrophic – Chronic
   b. Avoidable – Unavoidable
   c. Committed – Uncommitted
   d. Identifiable Individual vs Statistical
   e. Knowledgeable vs Unknowledgeable Risk

2. Illness and Disability (Avoidable)
   a. Major – Minor
   b. Temporary – Permanent
   c. Immediate – Latent
   d. Degree of suffering, dehabilitation, discomfort, etc.

3. Survival Factors
   a. Hunger Avoidance
   b. Shelter Availability
   c. Environmental Control (heat, light, etc.)
   d. Procreation – Individual, population

4. Exhaustible Resources
   a. Energy
   b Space (land)
   c. Environmental Quality
   d. Minerals, including water

5. Security
   a. Protection of rights, property, wealth

6. Belonging – Love
   a. Family
   b. Clique
   c. Group
   d. Society

7. Egocentric
   a. Power
   b. Wealth
   c. Fame
   d. Opportunity for Advancement
   e. Conspicuous Consumption

8. Self-Actualization
   a. Leisure
   b. Aesthetics
   c. Ethics
   d. Opportunity for Choice
   e. Freedom of Action
   f. Knowledge
   g. Quality of Life

Source: Rowe, 1975, p. 15.

although his terminology is different. His events (environmental problems) are characterized in the tabular columns by causative factors of society (population, income, consumption and technology), and by their magnitude (character of insult), temporal (problem threshold) and spatial (area affected) dimensions. These events are then grouped in the tabular rows by the order of the gravity of their consequences: amenity considerations, human health effects, human genetic and reproductive effects, and effects on ecological systems and the earth's life-supportive capacity. The resulting matrix exhibits a rough correlation between the increasing gravity of consequences and the greater magnitude, spatial and temporal dimensions of the events.

A different but not incompatible approach to a hierarchy of consequences is that developed by Rowe (1975) based on the conceptual hierarchy of individual human needs developed by Maslow (1954). In this hierarchy (Table 1.2) the highest priority need is survival, for which Rowe describes the adverse consequences as premature death, illness and disability, and other survival factors. Only when each need is met in order (the corresponding adverse consequences prevented), does the next ranking one become dominant.

That some hierarchies of consequences exist can readily be supported, but their exceptions need noting as well. History is replete with examples of those who chose not to survive in the face of 'fates worse than death.'

1.4 COPING ACTIONS

People survive and indeed prosper in the face of environmental hazard because they cope by adaptation and adjustment. *Adaptations* can be thought of as long-term responses to hazard that are deeply embedded in human biology or culture. Typical of these are the human adaptabilities to high altitudes or extreme cold. *Adjustments* are short-term responses to hazard purposefully or incidentally adopted. Adjustments take three major forms: measures that accept consequences by bearing, sharing or distributing the effects; measures that modify events or reduce the vulnerability of society to loss; and, on rare occasion, changes in basic location, livelihood or productive systems.

These purposeful adjustments vary tremendously by hazard and society, but are universally found. Almost all individuals and societies have more than one such adjustment at hand, although seldom is any individual or collective group aware of the entire range of adjustments. In a comparative study of natural hazards, enumerated adjustments range from a low of seven for drought in Yucatán to 263 for floods in Sri Lanka (Burton, Kates and White, forthcoming). The almost 5,000 interviews of the study showed that with the large number of available actions for coping, many, but not most, individuals seem to know of one or more actions that can be taken to reduce damage from the hazard. Many take some positive action to reduce losses, but few take preventive action much in advance of the hazard event, and few choose a large number of adjustments. In general, more people bear losses than share losses, more accept losses than reduce damages. Of those that reduce damages, more seem to try to modify events than to prevent consequences, and many more seek to reduce damages than change their livelihood, productive technique or land use. Fewer still move their residence or change location, even

TABLE 1.3 An Environmental Matrix (Part 2): Coping Actions

Environmental problems by order of gravity	Appropriate management level[a] 1. local 2. regional authority 3. national 4. multinational agreement or authority 5. global	Possible economic approaches 1. environmental charge 2. tax on material 3. subsidy	Possible institutional approaches 1. laws and regulations 2. enlarged systems management or planning 3. court actions	Possible technological approaches 1. contaminant at source 2. neutralization of objectionable discharges 3. reduction in discharge volume via process and material changes 4. increased recycling	Efficacy of possible value change bringing 1. reduced population growth 2. slower income growth and more equal distribution 3. less burdensome consumption patterns 4. curtailment of property rights
Amenity considerations					
Litter	1, 2	1, 3	1, 2	4, 3	3, 2
Noise	1	N	1	3, 1	N
Odor	1	N	1	2	N
Air, visibility aspects	1, 2	1, 3	1 2	3, 2	2, 3
Water quality, recreational aspects	1, 2, 4	All	All	All	2, 1
City, aesthetic aspects	1	2, 3	1, 2	N	4, 3
City, convenience and efficiency aspects	1, 2	All	2	N	4, 3, 2
Country, aesthetic aspects	2, 3	3	All	N	4, 2, 3, 1
Access to country and nature	1, 2, 3	2, 3	2	N	3, 1

Human health effects					
Air pollution combustion products	2, 3, 4	All	1, 2	All	3, 2
Water pollution:					
Pathogens	1, 2, 4	3	1, 2	2	1
Nitrates	1, 2	2, 3	1	3, 1	3, 4
Industrial chemicals	1, 2, 4	1, 2	1, 2	All	2, 1
Pesticides (via food chain	3, 4	2	1	3, 1	3
Radioactivity	3	N	1	3, 1	2, 1
Heavy metals	2, 3, 4	N	1	3, 1	N
Human genetic and reproductive effects					
Radioactivity	3, 5	N	1	3, 1	2, 1
Pesticides	3	2	1	3, 1	N
Industrial chemicals	3, 4	1, 2	1, 2	All	2, 3
Effects on ecological system and the earth's life supportive capacity					
Human occupancy of biospace	3, 5	All	All	1	2, 3, 1
Ocean threats:					
Pesticides	5	2	1	3	N
Oil	5	1	1	3, 2, 1	2, 3
Other chemicals	5	1, 2	1, 2	All	2, 3
Erosion	1, 3	3	1	3	4, 2, 1
Fertilizers and damage to mineral cycling	1, 3	2	1	N	2, 1
CO_2, albedo, and climate	3, 5	N	1, 2	3	2, 1
Heat rejection:					
Local aspect	2, 3, 4	1, 3	All	2	3
Global aspect	5	N	1	3	2, 3, 1

[a]Irrespective of source of financing.
N = none, unknown, uncertain, not applicable, negligible.
Adapted from: Brubaker, 1972, pp. 186–189.

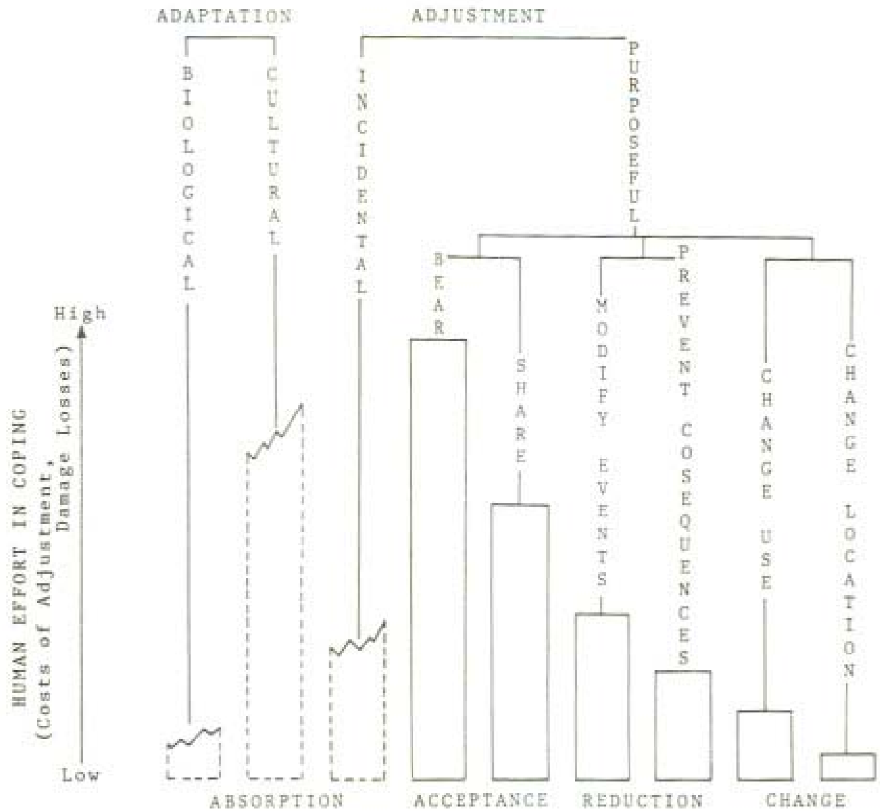

Figure 1.2 Coping actions and human effort

when the hazard is severe. A conceptualization of the human effort expended in coping is shown in Figure 1.2.

Together, adaptations and adjustments work to reduce the hazard consequences to some level of general tolerance. Such levels of tolerance can be thought of as related to coping actions – a threshold at which societal tolerance for loss or other consequences gives way to actions to reduce the consequences, and a further threshold of total intolerance leading to fundamental changes for avoiding the hazard potential. In considering actions for reducing or avoiding risk, Starr suggests that for developed countries there are two general levels of tolerance. One is related to voluntary exposure to death hazards at risks of 10^{-3} to 10^{-6} fatalities per hour of exposure and a thousandfold more stringent standard for involuntary exposure (Starr, 1972).

An example he cites is aviation safety. In the 1920's, risk from commercial aviation was about the same as general (private, pleasure) aviation today. Over that period, adjustments were developed to reduce such risk to the present level, which while maintained in the face of new aircraft, routes, etc., will probably not be much improved. Commercial aviation in its infancy, he implies, was a voluntary risk, as is general aviation today. Over time, it becomes a necessity, with stringent control applied until a balance is reached of societal risk and effort. Similarly, the low death rates from natural hazards in the United States may be close to the reasonably preventable annual minimum, and the focus is now on reducing property damage losses and preventing catastrophic deaths in large numbers rather than further prevention of isolated deaths.

Another coping distinction relates to the options of societies to encourage adoption of adjustments: doing nothing, facilitating voluntary choice by advice or warning, constraining or encouraging adoption, requiring various mandatory actions. Over time, with improved information and changing tolerance levels, there seems to be a discernible pattern. In controlling smoking or encouraging the use of seat belts for auto safety, there are clear sequences of increasingly strict actions, beginning with warning and ending with outright bans of smoking in certain places or mandatory use of seat belts enforced by law or technology. Another classification of coping actions is that used by Brubaker (1972) in his environmental matrix, distinguishing four approaches at various managerial scales: economic, institutional, technological and societal value changes (see Table 1.3).

From these various ways of describing and classifying adjustments, there emerges a picture of great complexity in the many ways individuals and societies can react to hazard. Added to the range of purposeful adjustments are other mechanisms which enable human beings to survive and even prosper in the face of environmental threat. These include incidental adjustments arising from activities whose purposes are remote from intentional hazard adjustments but whose net functional effect is to diminish the burden of hazard, and adjustment through unconscious shifts in individual cognition and affect in the direction of reducing the perceived or felt sense of threat and loss.

Coping with storm and drought, fire and disease, violence and war, are part of both the everyday and the extraordinary experience of society. For most of these hazards, the assessment of their risk is reasonably well organized and well understood. Of greater concern are the appropriate modes and levels of coping activity. It is for the newly discovered or newly created hazards, for the remote, rare and catastrophic, and, probably most important, for the undiscovered, that there is great need to improve and understand the ways in which we identify, appraise and compare environmental threat.