CHAPTER 13

ECOLOGICAL DIMENSIONS OF ENVIRONMENTAL HAZARDS

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1. Introduction

There is much to be gained in both theoretical insight and practical policy by looking at hazards as a set. Not doing so has resulted in great inconsistencies and inequities. Governments characteristically go to considerable lengths to protect their citizens from some hazards and neglect others of equal or greater threat [STARR, 1969]. The reason for this probably lies in the lack of a developed and applicable theory of hazard. Unlike "the economy," or "the transportation system," the hazard set is not a recognized category subject to management within consistent policy guidelines. An *ad hoc* strategy prevails in which one policy is developed for damaging events initiated by floods, another for drought, and so on. Hence inconsistency and inequity. Loss of one type may be covered by insurance while another is not. Government policies protect citizens against one hazard but not another, and compensation or special assistance is more likely to be given if large numbers of people are involved.

In this chapter a proposal is made for the development of theory by the application of a more thorough-going ecological approach to natural hazards. No precisely defined theory is presented, but an approach to theory is described. First, as background, the traditional paradigm of goegraphical research on hazards is described and some of its deficiencies noted. Second, some concepts are extracted from classical ecology as it applies to all organisms in the biosphere. Third, these concepts are related to the specifically human ecological questions in hazard research. In a fourth and final section some of the implications of the present level of ecological understanding of hazards are outlined, and the need is described for new theoretical approaches along ecological lines that might form a basis for more

[illegible]nt, equitable and environmentally sensitive policies.

2. The Traditional Paradigm

The traditional paradigm as developed in geographical research on natural hazards is itself ecological in the sense that the problem is defined as one of adjustment by human society to elements of an environment [BURTON, KATES and WHITE, 1968]. This research is in the tradition of geography as human ecology [BARROWS, 1923; HEWITT and HARE, forthcoming] and accords with the perspective of cognitive behavioralism [SPROUT and SPROUT, 1965].

It has been a dominant practice in this research, however, to identify hazards by initiating agent. Commonly recognized hazards such as floods, droughts and earthquakes are grouped according to their climatic, meteorological, geological or geomorphic origin. Each of the hazards listed in table 13.1 can be described in terms of magnitude, extent, frequency and other "hazard characteristics" [HEWITT, 1970; HEWITT and BURTON, 1971]. Human response involves consideration of these characteristics and the selection from a list of adjustments of those appropriate to the hazard. The selection depends on how the decision-maker perceives both the hazard and the available adjustments [WHITE, 1961]. Perception is treated as hazard-specific; that is, studies are made of how men perceive floods [KATES, 1962], earthquakes [JACKSON and MUKERJEE, 1972], drought [SAARINEN, 1966], and air pollution [AULICIEMS and BURTON, 1972]. Comparisons of perception of different hazards have been very limited [BURTON and MOON, 1971; MOON, 1971]. Such studies also deal with adjustments in hazard-specific terms, and although comparisons are made (table 13.2) when new hazards are added to the lexicon, adjustments are thought of as relating to the characteristics of that hazard [BURTON and MAY, 1972]. Furthermore, studies under the traditional paradigm are ecological in the sense that hazards themselves are viewed as joint products of man interacting with nature [KATES, 1971]. They have created a pool of information and ideas on the way individuals, communities and

table 12.1

Common Natural Hazards by Principal Causal Agent

Geophysical		Biological	
Climatic and Meteorological	Geophysical and Geomorphic	Floral	Faunal
Blizzards & Snow	Avalanches	Fungal Diseases for example:	Bacterial & Viral Diseases for example:
Droughts	Earthquakes	Athlete's foot	Influenza
Floods	Erosion (including soil erosion & shore and beach erosion)	Dutch elm	Malaria
Fog		Wheat stem rust	Typhus
Frost	Landslides	Blister rust	Bubonic Plague
Hailstorms	Shifting Sand	Infestations for example:	Venereal Disease
Heat Waves	Tsunamis	Weeds	Rabies
Hurricanes	Volcanic Eruptions	Phreatophytes	Hoof & Mouth Disease
Lightning strokes & Fires		Water hyacinth	Tobacco Mosaic
Tornadoes		Hay Fever	Infestations for example:
		Poison Ivy	Rabbits
			Termites
			Locusts
			Grasshoppers
			Venomous Animal Bites

Source: BURTON and KATES [1964, p. 415].

table 13.2

The Range of Theoretical Adjustments to Selected Environmental Events

Class of Adjustment	Event			
	Earthquake	Flood	Snow	Air Pollution
Modify natural events	Human alteration of earthquake mechanism has occurred accidentally. Research underway.	Reduce flood-flows by land-use (watershed) treatment, cloud seeding, reservoir storage, levees, channel improvement.	Change distribution by cloud seeding. Snow fences, snow removal, salting and sanding of highways.	Heat island effect. Giant ventilation systems proposed. No know way of controlling temperature inversions.
Modify human use	Stable site selection, building design, land-use change and regulation.	Flood-proofing, building elevation, land-use change and regulation.	Building design, seasonal adjustments (snow tires, chains, seasonal migration).	Reduce emissions by changes in heating, energy and transportation systems. Planning for dispersion of effluent sources.
Emergency adjustments	Warnings, evacuation, fire-fighting, disease control. Take shelter.	Warnings, evacuation, flood-fighting. Elevate contents of buildings and people to a higher floor.	Designation of emergency snow routes, rescheduling activities, use of alternative forms of transportation. Stay at home.	Temporary reduction of emissions, temporar evacuation. Stop sm in wear a mask, keep o of high pollution zone
Adjust to losses	Public relief, insurance, bear the loss, compensation.	Public relief, insurance, bear the loss, compensation.	Public relief, insurance, bear the loss, compensation.	Public relief, insurance bear the loss, compensation.

national governments respond to hazards within certain well-known and well-established categories. As information has expanded and insights deepened, however, the initial categories have tended to break down. Treating hazards in terms of floods, earthquakes, droughts and the like, and the examination of response in hazard-specific terms becomes an impediment to a broader theoretical understanding of human response.

A formulation of the problem is needed which can take account and deal more effectively with some of the following complexities which fall somewhat uncomfortably within the traditional paradigm:

1. No event, however extreme, can be described as an unmitigated loss. One man's hazard is always another man's resource. The extra rainfall that causes a flood may elsewhere improve crop yields, replenish diminished water supplies and add to the power-generating capacity of a river.

2. Response to hazard is not uniquely defined from the size or type of event. Response to a flash flood may bear more similarity to response to a tornado or earthquake that to a slow onset flood on a major river. Floods of this type may be more akin to drought events, in terms of the pattern of human response they call forth.

3. The scale of damage over many hazard events is not a clear function of the magnitude of the initiating event. The relationship between size of event, as measured in physical terms, and the amount of damage resulting is irregular, changing over time and dependent upon many other intervening variables.

These considerations lead to the search for other ways of examining hazard events, in which hazards are seen not as separate discrete phenomena but as an integral part of an on-going system.

The fluctuation of a geophysical variable in relation to human action is shown in a hypothetical example in fig. 13.1. The level of the damage threshold may be seen to change when certain actions are taken to reduce potential damage. Also, the effective pattern of fluctuation of the geophysical variable itself changes when control works are introduced. The diagram gives some idea of the complexity of the

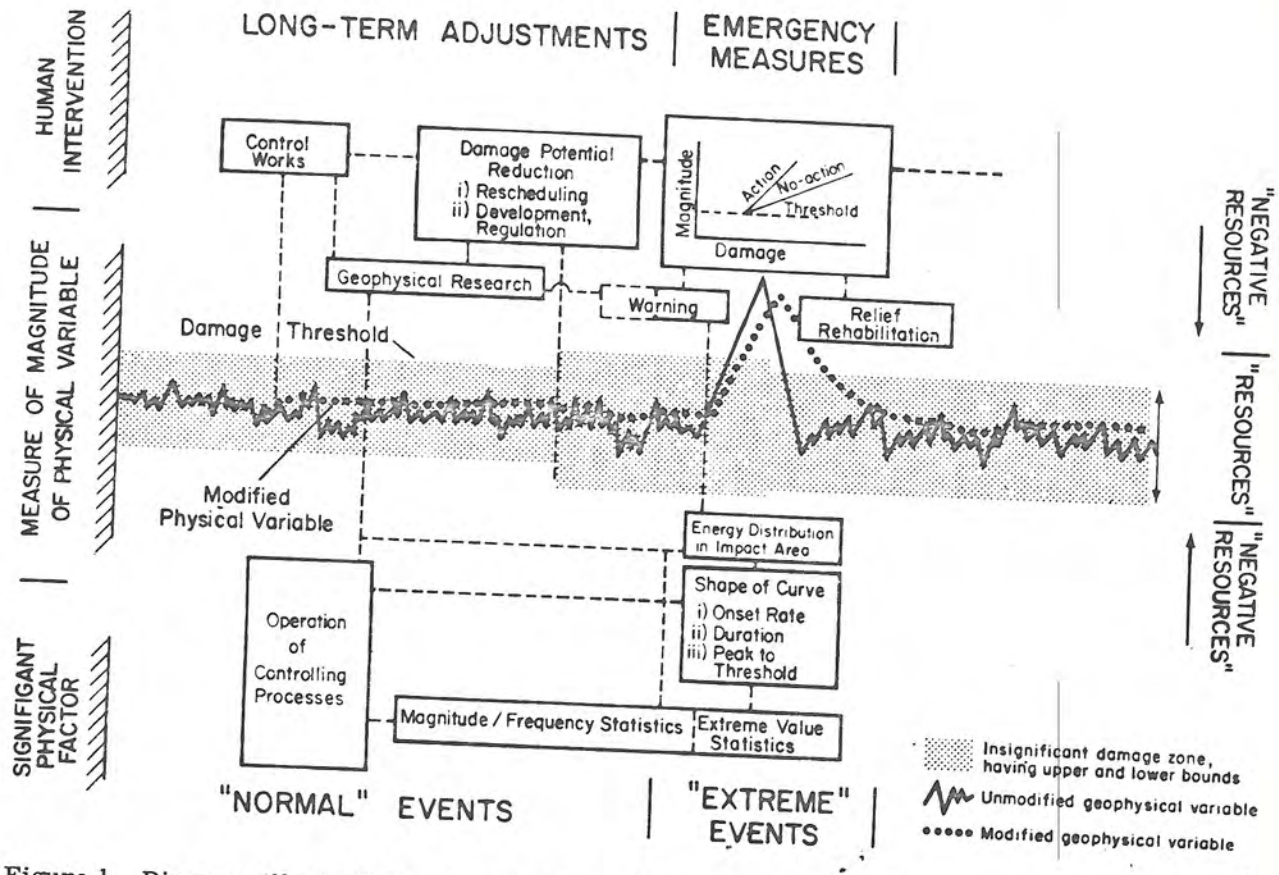


Figure 1. Diagram illustrating relation of a geophysical variable to human action

interrelationship between continuously fluctuating damage threshold values and the question of a modified or unmodified geophysical variable. The diagram still places emphasis on one variable, however, and the various effects, benefits and losses are all aggregated to give a single "net" measure of interaction [HEWITT and BURTON, 1971].

Another perspective is added by considering just which components or functions of a human economy are threatened by hazards. It can be shown that, broadly defined, there are some six ways in which human biological, social or technological processes can be disrupted by damaging events. Though not mutually exclusive for any given damaging events, the types of disruption may be described as follows:

"1. Mechanical Impact: where 'loading' in the broad sense damages structures, persons, etc. This may be dynamic loading such as occurs in wave action and seismic tremors, or static loading, such as occurs in the build-up of snow on a roof, or icing of a ship's hull.

2. Physical Barrier: Where the natural agent is not directly 'attacking' some human structure or activity, but blocks or greatly impedes the movement of men, vehicles, goods, and/or information. The barrier may be discrete, such as a lava flow or avalanche across a road, or continuous, such as snow or flood water covering the countryside, or pack-ice at sea.

3. Sensing Interference: the situation in which human or artificial sensing devices are prevented from appraising the surroundings. Examples range from 'Ice Blink' with sea ice, fog, or the icing of vehicle windshields to failure of warning systems. Note that the essential difference between this and a physical barrier is that, for instance, routeways may be open to traffic but with fog they cannot be seen properly.

4. 'Novel Environment' Hazard: the situation where the environment is not directly damaging but the equipment an organism employs encounters situations which it cannot deal with. Thus, in the case of ice on the road, a driver may see it; it is not a physical barrier; and does not 'load' the vehicle, yet control of the vehicle may be lost with damaging results. The combination of man and vehicle cannot deal with this contingency so as to perform intended

activities. One might extend this broad category to inadequacies of physiological, psychological, or social equipment. It is hard to express this kind of immediate condition set by an environment, or to give it a satisfactory name.

5. Deprivation: cut-off or displacement of essential life-support requirements of organisms. In this situation the flow of goods to, or boundary conditions of, the organism are inadequate or toxic. The circumstances range from drowning in water, through drought from inadequate water supply, to forest fire conditions.

6. Contamination and Deterioration: where materials suffer loss of 'quality' either immediately or through persistence of a hazard situation. An obvious case is damage to stored goods by flood water." [HEWITT and BURTON, 1971, pp. 132-3].

While somewhat elementary as described here, it can be seen that these categories suggest a more thorough-going ecological approach to hazards than that which studies only the individual event or starts with classes of initiating agents. The way in which the usual adaptations, activities or economic patterns are disrupted is emphasized, and hence the place of hazards in the general system of relations between man and environment. However, we have not previously attempted to show how this work might be related directly to classical ecological concepts.

3. Parallel Concepts in Ecology and Hazards Research

Before attempting to describe or define the human ecology of environmental hazards, we shall note some of the parallels that exist between ecology and hazards research. The former has developed primarily in the context of "natural" communities, while the latter is a body of environmental science research, working especially at the interface of social science, planning and natural science. For brevity we assume some knowledge of the general nature and role of the ecological concepts described. They can, however, be followed up in the literature cited and the more

detailed ecological discussions elsewhere in [illegible] purpose is to indicate some of the main points at issue by indicating similarities and differences of approach in the two fields of investigation.

An important distinction can be made between hazardous places and hazardous events. Ecological work has tended to emphasize the former while hazards work usually relates to the latter. A hazardous place is one where an organism, given its biological, social, and in man's case, cultural attributes, cannot adequately deal with the normal environmental conditions. Here there will be an almost continuous threat to life and economy. In most of the natural world, such inhospitable or marginal areas can be defined relative to the geographical distribution of species, and the limits of the biosphere on high mountains or ice caps. Hazardous events may be broadly defined as events which certainly occur everywhere, but are not sufficiently frequent within the normal geographic range of a creature or society to impede drastically their long-term viability. Perhaps more significant from an adaptational point of view, hazardous events tend to be too infrequent for the society to become fully adjusted to them. Hence it does not cease to be endangered by these events. While there is a whole range of intermediate cases to which chronic hazards of disease, accidents and pollution being identified today bear witness, hazards research has focussed upon sharply defined events of rare occurrence and extreme magnitude.

3.1 Hazards and Toleration Ecology

One of the more obvious comparisons that can be made is between hazards research and toleration ecology [SHELFORD, 1911, 1913; LEVITT, 1963]. An important notion in the study of natural hazards has been that of damage thresholds [see HEWITT and BURTON, 1971, pp. 13, 130]. For example, where built structures are subject to varying mechanical stresses, we may define thresholds of dynamic loading above which parts or all of the structures will fail [c.f. FERRY BORGES and CASTANHETA, 1971]. Within some range of statistical error, hazards may be defined in terms of

design specifications for limiting performance of the structures or their parts. Where it is possible to relate failure directly to some value of environmental stress, it may also be feasible to specify the statistical frequency of hazard occurrence, given long-term records. In this way degree of risk from wind or seismic loading, snow depths, rainfall intensity, flood height or landslides may be defined in terms of magnitude and frequency of impact. Since the events can be defined in terms of the form and extent of damage, these depending upon the performance thresholds of structures, some estimate of costs and benefits associated with the hazard can also be determined. The case of engineering safety affords perhaps the simplest use of the threshold concept. However, there is some basis for applying the same notion to the more dynamic aspects of economy and society. The capability of medical and other social services to perform certain functions may be quantified in terms of demand thresholds beyond which service will be overloaded and break down. The budget of an institution, the human and natural resources of a community, and the demands of a given population admit of the same treatment. Events which place stresses on a society over and above these thresholds will be automatically apparent as hazards, and hazards of a particular degree of severity.

In a similar way, ecologists have set out to define the limits of tolerance of organisms [ODUM, 1959, p. 93]. It is hypothesized that each exchange between an organism and its environment implies a curve, or set of curves that vary with time and situation, related to the performance and survival of the organism. Toleration ecology is especially concerned with the limits or threshold values on curves of say, temperature, moisture supply or chemical concentrations, beyond which organismic functions are damaged or destroyed. Again, some uncertainty is involved in the specification of actual values, and when the notion is extended to a species population it implies a bundle of curves associated with genetic polymorphism, and the variation in inhabited niches. The whole bundle of curves, and especially the limits of tolerance on them are an idealized way to picutre the fundamental niche for a species [HUTCHINSON, 1958]. This is generally broader than particular realized

niches, and is most clearly related to hazards for individual and community since it defines the limiting range of manageable environmental stresses.

Nevertheless, there are some ambiguities in the relation of these notions in ecology and hazards research. A problem which has greatly limited the interest of toleration ecology is that while the limits for an organism indicate its long-term adaptations to environment, and the bounds within which it must function, the approach can tell us little about how organisms stay within those limits. The point is rather crucial for deciding whether a particular environmental state is hazardous or not. It is not surprising, in fact, that in hazards work there is a poor correlation between measures of, say, geophysical variables, and amount of damage. The large spread of values may be attributed to the role of dynamic elements in culture and response to stress, and has parallels in the adaptability exhibited by most organisms. Our limits of tolerance and the curves on which they are defined only deal with the magnitude of exchanges between organism or society and environment. Quite as important is the ordering or patterns of relations between creature and milieu. Survival and viability of living things depends more upon the ability to make active adjustments to the range of states and rates of change in environment than on mere magnitudes of exchange [see ASHBY, 1966]. Further, an organism does not literally adjust to specific values of environmental variables except in its simplest vegetative functions. Rather, its response to specific items must be integrated with its overall needs. This high-level ability to synthesize adjustments to the stream of environmental contingencies tends to belie any simple one-to-one relation of hazard and response. It also leaves some scope for novel response, and these can be expecially important in the case of rare and extreme events [c.f. MAYR, 1963]. Expressing and quantifying adaptability in organismic response has proved far less simple than defining ultimate failure or death from unavoidable extremes. One cannot easily expose creatures to such extremes without restraining many of their other faculties!

When studying man, it is also true that the kinds of variables usually employed in toleration ecology are of marginal significance in most hazards. Physiological tolerance of temperature, humidity, thirst, toxic substances, radiation or mechanical impact becomes very important where individuals are exposed to extreme geographical environments. They are also important in chronic hazards such as air pollution. In many extreme events, however, they are only indirectly or not at all involved. We do not deny the importance of physical suffering, especially during natural disasters in poor countries, and in such things as transportation accidents in wealthy ones. However, the usefulness of measures of tolerance in such cases is rather marginal. Instead, as indicated above, one must use broader measures of the ability of a community to respond to certain levels of injury and decimation distributed through its population. Again, the extent of distributed physical hardship is usually poorly correlated with the magnitude of initiating events such as earthquakes or crop failure. So far as we know there has been no extension of toleration ecology to deal with limiting responses of whole communities and species population, though there clearly are parallels in the study of checks and balances in population dynamics. As we shall indicate, however, this work tends to have a differing orientation and interpretive role from that of hazards research.

With modern urban-industrial societies we must also recognize that hazards are not only or mainly related to physiological damage even in an indirect sense. Rather it is our artifacts, institutions and so-called external metabolic functions (e.g. industrial processes, and engineered environments) that receive the brunt of most damaging events. There may be a very broad range of damage to these items, expressed in economic terms, over which we can discern no definite impact upon the physiological well-being of a community. We return to these issues in the next section.

In general, it seems there are close parallels between the approaches which study the classification of degrees of damage due to hazards, and limits of tolerance in organisms. If tolerance were to be extended to include the stability and responses of whole communities, and attributes other than the purely physiological, the

coordination of the two areas might be complete. Nevertheless, this whole approach is very restricted in its ability to define and understand hazards or responses to damaging events by individuals and communities. The main attraction of toleration research is, that like hazards research, it defines what is "good and bad" in an environment from the point of view of the individual and species. Broader ecological perspectives do not tend to do this, as we shall see. Nevertheless, our experience with hazards to man is much the same as that in toleration ecology, namely that to provide a basis of understanding we must go beyond the nature of potential and inflicted damage and study the overall functioning of communities.

3.2 Hazards, Resources and Ecosystems

Parallels are often drawn between ecological modelling of natural communities and economic descriptions of human communities [e.g. BATES, 1961, p. 94]. The roots of the word ecology give us the concept of the "household" which is involved in the life of any organism, and which can be expressed as a relation between the organism's material needs and environing resources. Lindeman's "trophic-dynamic" approach to ecology has given particular impetus to the view, and it is now central to most ecosystem modelling [LINDEMAN, 1942]. The equivalence to studies of man's resources and resource systems is clear, especially to so-called natural resources and agricultural systems. One way in which we have attempted to integrate the general study of resources systems with hazards research is to describe hazards as "negative resources." This is particularly apt for many hydrologic, atmospheric or biotic hazards since they are often only hazards in the extreme range, and resources in the manageable range. The case of river flow versus floods is an obvious example. The description of hazards in this way is also convenient because, in fact, damage is not only nor usually confined to single, isolated events. At the lower end of the scale damage is synonymous with the unavoidable wear and tear of all economic activities. While there are, as we have said, thresholds above which damage is peculiarly disruptive to a community, there is usually a continuous range of losses

above and below these thresholds. The ways in which manageable levels of damage are dealt with by a society are quite as important to understanding hazards as the response to serious disruption. Monitoring the gains (resources) and losses (hazards) at particular levels of economic activity is a more powerful way of examining hazards than simply treating extreme events. Thus a hazard relates to the damage to a community and the costs of offsetting, recuperating from, or preventing such damage. In the first place, resources are actually being destroyed and, in the second, they are being diverted from other uses. Parallels with ecological modelling could be drawn along these lines. However, we may learn more by indicating certain incompatabilities of the two fields in this regard.

Ecology is the heir to that old debate about whether Nature is essentially a benign and harmonious old lady, or a wasteful and callous one. Many ecologists find the most reasonable view of what appear to be destructive and wasteful events, that they are really necessary and valuable parts of the natural order. It can be argued that there is no such thing as "waste" in nature. Damage and loss in one species or community are usually advantageous to others. The complexity of the organic world appears designed to absorb and take advantage of all but the most catastrophic events. The precariousness of existence is a prerequisite of the long-run health and adaptability of organisms. This view of nature puts far more stress upon the accomodation of individual and community to the general balance of living systems. Hazards become only those things which disrupt and destroy the patterns and stability of entire communities. And even these events may pale as hazards in the very long term since they then appear as guiding episodes in the general evolution of life. Thus, one of the main themes of modern ecology leads to a highly abstract and detached view of hazards to life - one which defines "hazards" as those events which seriously undermine the overall patterns and variety of life, or threaten all life on earth. We are now aware that the impact of man's exploitation of resources, his unchecked population growth, military power and pollution of environment pose such ultimate "eco-catastrophes."

It must be said that our view of hazards is [illegible] anthropocentric one, and perhaps even more accurately the ethnocentric view of Western man. Even though a good deal of modern ecology has chosen "productivity" as its principal measure of ecosystem functioning, its general attitude has been more dispassionate that that in hazards research. In part this relates to a lack of sophistication in much of the literature on resources. There has been a tendency to overemphasize quantities of resources for future exploitation. But inventories of available resources provide minimal ecological insight. The latter relates rather to the dynamics and form of those systems involving the movement and storage of matter or energy in the biosphere. At particular points these act as the resource base for a particular organism or community. Such a dynamic view has been further masked in studies of human resources, owing to the Western emphasis upon items having a relatively fixed storage term and little natural turnover, such as fossil fuels, ores, or real estate. This has encouraged a fairly static view of resources per se with man as the only active agency. Neither the study of hazardous events nor of biosphere activities fits well into this mold.

In the biosphere it is the relatively rapid exchanges between atmosphere, hydrosphere, green plants, soils, browsers and so on, that are more crucial. It is these same fluctuating systems which are most commonly involved in environmental hazards. The sources of danger and damage to a community usually lie in the more extreme fluctuations of the larger exchange systems or in their disruption. Where hazards depend on conditions external to a community, damaging events can be defined in terms of the fluctuations in magnitude of environmental variables.

In an ecological view, the internal aspects of a living community are equally important. In relation to the resource base, population size and dynamics are most commonly used to describe the community. Seasonal and other rhythms of activity may, however, be at least as important. The impact of a given fluctuation in environing conditions will be dependent upon the particular state of the community. Indeed, in the case of such matters as predation, disease outbreaks or territorial competition

"external" hazard seems to be brought into play by the state of health and vigor of the community. In terms of the economy of a community, hazards appear, therefore, to be a function of relations between the dynamics of supply systems, population, and rhythms of resource use. Yet it soon becomes clear that this ecosystem view returns us to the point that damage to individual segments of living communities is not necessarily damaging to the whole community. Indeed it may be beneficial, expressing the natural tendency of the living system to attempt to stabilize itself in relation to changing environment or internal conditions. However, in practice we find it hard to apply such a self-effacing view of hazards even to the small discomforts of our daily life! There is growing evidence that we must and should do so for the general health of our planet, but that aspect does not seem applicable to many of the damaging events we study in natural hazards research. Here there is still some hope that we may reduce damage without unfortunate side-effects.

3.3 Species and Hazards

The materialistic view of ecosystems sometimes makes us overlook matters which have assumed increasing importance in hazards research, and may be identified as the view from within the living organism [SAARINEN, 1969]. This relates to the other face of ecology in which the behavior, social interaction, growth and reproduction, the methods of adaptation and adjustment in each species appear in the forms of observable communities.

As users of resources, organisms are never simply sections of piping that convey or store energy and materials. They are active participants, obtaining, maintaining and transforming resource materials. In doing so, they bring to bear their peculiarities of physiology, sensing, mobility and society upon the general operation of a community. In the long run enormous pressures serve to accomodate each species to its community and biome. Yet, apparently this is achieved by individuals who hoe their own furrow in an exclusive, species-world. Whatever the grand design, resources, hazards, and environment generally, are not fixed and objective phenomena. They are

defined by the subjective needs and awarenesses of individual species. Our work on environmental hazards has been carried out on scales of time and space where the species-specific, or in man's case culture-specific definition of environment looms very large.

The ecology of living communities shows a partitioning of habitats and functions by discrete species populations. There are some basic processes in the inter-relations of species and environments which insure that this is so. Organisms which adopt or are forced into novel uses of environment - that is, new ecological niches - if they survive, are rapidly differentiated from their parent species. Hence the living world is almost entirely composed of visually and reproductively isolated species [MAYR, 1963]. The ecological correlate is the mosaic of discrete niches occupied by species. Again, the separation of similar or overlapping niche-dwellers tends to occur very quickly, presumably after the manner described in probabilistic models of the competitive exclusion principle [HARDIN, 1960; BARTLETT, 1957]. Thus the behavioral and perceptual isolation of species or niche-dwellers is a fundamental compliment, rather than a contradiction of the interconnectedness of living systems. Here is found a balanced, if less obvious, definition of hazards. Natural eco-systems are certainly more complex and, in terms of diversity, more stable than any system devised by man. That does not mean they are perfect, or that the individual or species is powerless to reduce local stresses without upsetting the larger design. It does focus attention upon the real if constrained adaptability of all organisms and ecosystems. Adaptability lies in the physiological, perceptual and social controls which organisms can use to maintain their bodies and communities within tolerable limits, as environment or population fluctuates.

1.4 Uncertainty and Hazards

When we attempt to model the general role of hazards in the activities of human communities, we find that the notions of risk and uncertainty play a large part. Degree of damage associated with hazards exhibits a wide range of values in

most cases, and as a general rule, the more severe the damage the less frequently it occurs. Furthermore, the less frequent an event, in general the less predictable it its occurrence. These features would seem to be a necessary corollary of the existence of viable communities of any kind. Adaptation to environment soon becomes impossible as the range, rapidity and unpredictability of environmental change increases [c.f. ASHBY, 1966]. At the same time, the less frequent a particular kind of event, the weaker tends to be its role as a component in selection pressures. In human terms we would apply the notion of diminishing returns. Other things being equal, the less frequent an event or state, the less it pays to tie up resources (or adaptations) to deal with it. In this regard, spatial frequency is, of course, as important as temporal frequency. If damaging events only affect a small part of an organized society, survival, recuperation and emergency aid are assured. Again, the larger the area of a damaging event, in general the rarer its occurrence, but also, the less predictable it is. This would appear to apply to most physical and social processes. We can identify earthquake-prone regions, areas likely to be struck by tornadoes, hurricanes or volcanic eruptions. But even where there is some capability for short-term warnings, pin-pointing where and when major natural disasters will occur from such events is to a very large extent still not possible. The reasons seem to lie quite as much in the inherent uncertainties involved in rare and extreme events, as in our ignorance of physical processes [HEWITT, 1970]. Parallels can be drawn in the social realm. "Black spots" on roads, communities liable to riot, and international hot spots can be zoned, but the more serious damaging events of such types cannot usually be predicted with any precision. Again there is no reason to suppose this merely a matter of ignorance rather than of the degree of randomness inherent in such events.

In this sense the stronger parallels with ecological work are towards statistical population models, and probabilistic interpretations of natural selection, though once more the intent of such studies has rarely been quite the same as that in hazards research. Overall, we may see, however, that the kinds of undertainties dealt with

in this area of ecology are just those which arise in the "no man's land" between the well-defined needs and behaviors of individual species, and the general functions of complex communities or ecosystems.

It is this same sort of "no man's land" that we are especially concerned with in the study of environmental hazards and the possibilities for reducing their impact upon human life and economy. Human adjustments to hazards are evidently bounded by the initiatives which overall human and natural resource systems can withstand, and by the perceptions, values, and needs of groups of human beings. But between these two domains there is a large measure of uncertainty to be taken into account when studying particular damaging events and adjustments to them. And there may be severe limits upon our ability to reduce this uncertainty by research into causal mechanisms.

4.0. Human Ecology and Hazards

4.1 Man in Nature

There is a strong case for man adopting a humbler and more accomodating attitude towards the rest of nature than has been apparent in recent years. But this should not be allied to the importing of a naive naturalism into human ecology along with valuable ecological perspectives. Certainly, most of the biological and ecological processes that apply to the rest of the biosphere apply to man. Environmental selection pressures are at work on human genetic composition and variation. The particular geographical location and resource uses of any human community have strong reciprocal consequences within that community.

Man's use of materials and energy, and his place in global ecosystems can be modelled quite effectively using the same storage and flow measures that apply to the rest of the biosphere [McHALE, 1970; ODUM, 1971; SINGER, 1970]. But this gives quite an indirect indicator of how and why man is radically transforming his place in nature and the ecology of the planet.

The problem is that, in the modern world especially, operation of "natural"

ecological processes is either quite indirect or trivial as an explanation of human activities. In the usual ecological sense only minute aspects of human diversity are explained by genetic variation, and man is not a "niche-dweller." The main discoveries of anthropology are that the same species inhabits an endless variety of environments. Racial differences have only a tiny and often contradictory relation to cultural differences. Man occupies a wide range of niches, and shows a huge capacity for innovation in environmental exchanges.

Literally defined, man's "fundamental niche" embraces a set at least as large as all the present and past economies of the species, and probably a much larger one. The most we can say in these terms is that each distinct group of men occupies, as its "realized niche" a certain eco-cultural domain. When we turn to modern human ecology, this domain has, as its central fact, the urban-industrial "ecosystem." The bulk of modern environmental hazards to man and global ecology, whether we are speaking of the Third World or the West, relate primarily to those things which distinguish man from the rest of nature, and modern man from his archaic ancestors. The problem is for our human ecology to take account of these conditions without severing itself from the rest of the life sciences.

4.2 Cultural Ecology

Ecology is concerned with the conditions and exchanges that relate organism and environment. The most distinctive and powerful relations between man and environment have to do with his brain and capacity for abstraction. Their broader manifestations are what we call culture. Man perceives and retains environmental experience in symbolic patterns broadly termed knowledge. He can direct attention to parts of that knowledge, and manipulate it by means of the symbolic structures and value frameworks which hold the knowledge together. From this comes a certain sense of reality, of his place in it, and of intentions towards it. These can be used to co-ordinate his senses, limbs and means of communication so as to bring to bear energy, materials and persons upon certain aspects of environment. The resulting transformations (or

conservation) of environmental conditions are limited only by natural laws, the extent of our knowledge, our sensitivity and power. The product is artifice. It appears in the "man-made landscapes" of the settled world, with urban-industrial society its most drastic expression. Its most immediate features are, of course, the technologies and artifacts of different peoples, and their social structures. These intervene in and radically alter the significance of relations between man's biology and planetary environments, and hence in his proneness to hazards. In the rest of nature the only things which intervene between an organism and the operation of "blind" natural processes are the other organisms which synthesize its food, utilize its waste, or modify microclimate and other niche-variables. For modern man these functions are mainly performed by his artifacts, the surrounding social structure and his ability to redesign the environment.

As a species, we do not merely lack many of the built-in checks and balances that govern other animal populations; we have developed a distinct distaste for allowing these things to control our activities. Whereas genetic controls, negative feedback and well-defined niche-occupance dominate the ecology of other creatures, modern human ecology is distinguished by cultural regulation through mass, symbolic communications; by technological innovation and manipulation of environment; by positive feedback in population and resource use; and by expanding "eco-cultural niches" [c.f. HELM, 1962].

There is a vast literature relevant to this whole field of what can be described as cultural ecology. We can only cast an approving glance in its direction and proceed to the specific issues of hazards to man [see HEWITT and HARE, forthcoming; WAGNER, 1960, 1972; MIKESELL, 1972].

4.3 Hazards in the Modern World

One manifestation of the undue "naturalism" of much human ecology is the tendency to view only physiological needs as sources of man's vulnerability. Although what we have said concerning toleration ecology seems fairly obvious, many still adopt the

view that only food, sex and shelter are man's real needs. But all the circumstances and products of what we have termed human artifice are as much, and often more liable to damage than our bodies. Our beliefs, peace of mind, social systems, artifacts and techniques are expressions of "hungers" whose satisfaction is equally, sometimes more, important than physical comfort. In the modern world institutions and artifacts are the items which filter most of the damage, or are damaged most by environmental hazards. Certainly, starvation, thirst, temperature exposure or any severe pain or damage to bodily organs are debilitating, dehumanizing conditions that eclipse all other matters. But the ways in which these arise, where they are prevalent and the extent to which they feature in environmental stress on modern urban man must be seen to relate mainly to the other human products and needs.

We would argue that the human context of major environmental hazards of today is the modern urban-industrial system and its external effects. However, it is a system whose "ecological" interpretation both as an ecosystem in itself, and in relation to the rest of ecology is still poorly articulated. But it seems more important to sketch some of the elements involved in such an interpretation than to ignore the issue.

In the Western world one can see the place of environmental hazards in terms of the following simple structure. The organism man, his biological needs, feelings and mental welfare are still, we like to think, center stage. But he is rarely in direct or uninterrupted contact with unmanaged planetary processes. Instead, his immediate environments - those he considers and relates to most, and through which he is most likely to suffer damage - are a more or less complete surrounding of built objects, culturally filtered information and ideas, and the socially organized behaviors of other people. An abstract system of monitoring called economics is about the only way to keep track of modern man's "household." Responses to particular aspects of the human and planetary environment are almost all given over to specialized institutions or professions. There is, in other words, an artificial habitat facing inwards towards people. The same artificial complex is also directed outwards as

the dominant form of contact between our human society and planetary environments. In this outward-facing aspect of culture, most of the contacts are effected and controlled by the use of technology. The number of persons involved is small and decreases every year. It is a much vaunted arrangement. It has enabled us to syphon off ever larger quantities of materials and energy from the biosphere while cushioning most people much of the time against the vagaries of nature. The place of environmental hazards in this simple three layer arrangement is fairly clear. In the main, the known and felt sources of damage to most of us are parts of the cultural and economic surroundings rather than "nature." Further, it is only towards the former that we have substantial experience in adjusting. More specifically, our income, job, age or ethnic group tend to give us experience in adjusting only to a small segment of the socio-economic order. It is hardly surprising that hazards investigations, even in major disasters, show that the bulk of an impacted population mostly responds in accordance with normal positions and roles in society [QUARANTELLI and DYNES, 1970]. The findings are essentially like Camus' tale of a modern town suddenly in the grip of bubonic plague. He shows most of the town taking weeks and even months to accept and redefine their relations to the novel environment even in light of such a hideous and pervasive hazard. Of course, man's cultural traits dominate his activity even in small archaic societies. What is particularly important is the scale of urban-industrialism. More and more people are coming to relate to this huge, impersonal way of life as to "natural" forces. The environmentalist sees a strange similarity between the aggressive, exploitative attitude of many Western people towards their cities, institutions and services, and the attitude to natural resources that developed earlier. The fact that most North Americans and West Europeans seem to rank socio-economic hazards above the old types of natural hazards makes a good deal of sense. Their ecology is firstly one of artifice, but on the scale of Nature.

4.4 Simplification

Hazards to and from the planetary environment need to be examined in terms of

the process of environmental simplification. Contrary to the prevailing belief of the age, modern urban civilization is not the most complex system on earth - at least, not compared to the natural and cultural ecologies over equivalent areas in the past. As a corollary of its cushioning of urban-industrial people against disruptive events, the outwardly directed part of our civilization forcefully works to reduce the variety of natural and cultural situations it must deal with. Much of modern technology has been researched and designed so as to remove the need for people to adapt to different environemnts. Air conditioners and anti-freeze are obvious examples. More directly, mechanized farming, dams and irrigation, pesticides and fertilizers, hybrid plants and animals, canneries, all-terrain vehicles, and frost resistent building materials have the same effect. They truncate the biotic, climatic and terrain variety of given environments, smooth out temporal fluctuations and bend biotic productivity so that all become tributary to, and more easily controlled by a large economic system. Overwhelmingly, the choice of control reflects the interests and preferences of the more powerful economies.

And it becomes increasingly clear from the ecological viewpoint that this is an embattled system on all fronts. All the common tendencies of natural and human communities are towards diversification and a sensitive response to environmental diversity. Only the massive funnelling of raw materials and fossil fuels into our endeavors allows us to contain those tendencies. The student of hazards is particularly aware of the limits to that containment. The net effect has been to dampen down small and medium scale sources of disruption in society and Nature. Social services, public health authorities, police and fiscal hand-outs contain the former; engineering technology is the main means to contain the latter. But there is always a type or scale of disruption too large or obscure to be predicted or controlled. These larger events have come to be an ever greater threat and to have an ever greater impact. When an extreme geophysical event cuts through our surround of artifacts and institutions, its impact on our untrained, unprepared minds and bodies is all the more devastating. The wealth tied up in the items designed to protect us is vast and

...s loss all the greater. O ten it can only be withstood by redistribution on the ...ale of the nation or the international community. The disruption, economic loss ...d death toll in old style natural disasters was usually very small compared to the ...co-cultural catastrophes" of our wars, dust bowls, and economic depressions.

The scale of chronic hazards related directly to man's activities has greatly increased. The toll of transportational and industrial accidents exceeds in scale of cost and deaths the great plagues of earlier urban civilizations. Diseases of heart and lungs related to socially induced habits affect millions, and our impact on the air, water and life of the planet is a constant threat to our own welfare. It is in an ecological context - the context of an overview of interrelated events, and their relation to how ecosystems function - that one must emphasize the unfortunate aspects of modern civilization. There has been a large price paid for the comforts we enjoy. These comforts are very recent and far more precarious than is commonly realized. I ...s in light of this tension that other elements of hazards pale.

In underdeveloped countries the effects are different but the impact of Western ...ques and ideas on changed vulnerability of their communities is clear. Modern ...dicine, aid and scientific farming have served to produce vastly overpopulated ...ions in cultures lacking the wealth and expertise to redress the condition. Pop... ...ons are constantly at levels close to or beyond the absolute capacity of their source base to provide even minimal requirements. In the absence of sophisticated ...chnology, social services and environmental monitoring, the impact of extreme ...ents has grown to alarming proportions. There were precedents in the disasters ... the densely populated riverine areas of old China and India, but never has there ...en so frequent an occurrence of massive loss of life and economic havoc wrought by ...ural hazards as we have witnessed recently in East Pakistan, Peru, and East Africa ... each case we are speaking of areas where population has exploded under the kindl... ...ivities of Western altruism and expertise. The problem seems to have lain in l... ... perspective upon the overall requirements of stable and prosperous communities ...er differing environmental, cultural and technological conditions.

And we have to add to our tale of woe here, the great and growing loss of life

and disruption due to military and paramilitary activities in Third World countries, and the spectre of mass starvation which now endangers whole nations, should their often very precarious new, or overloaded old resource system fail, or population continue its upward spiral. While hazards research can look to a greatly increased capability of modern engineering and social services to combat hazards in wealthy nations, this seems to be offset by increasing inability to handle similar hazards in poor nations, and an increased overall danger to human ecosystems if failure does occur. Here then, hazards research tends to merge with the concerns of those ecologists who see grave dangers in the general activities of modern man in resource use, waste disposal and population growth.

5.0 Implications and Needs

A dominant approach in public policy to deal with hazards in the environment has been to seek means for their control or modification [BURTON, KATES and WHITE, 1968]. Thus, when flood waters sweep through urban areas or overflow onto a farmland, dams and levees are built to contain them. Sea defenses are constructed to hold the violence of storms at bay, and cloud seeding experiments, as in Project Sotrmfury, are conducted to try to modify wind and rain intensity in hurricanes. Heavy expenditures are accepted without serious question as part of the normal course of events for snow removal, for irrigation in sub-humid and arid regions, for hail supression and for many similar attempts to cushion men against the vagaries of environment.

This approach, characterized by its lack of ecological perspective, persists despite mounting evidence that it is generally unsuccessful and may only serve to exacerbate the problems it is intended to solve. When the design capacity of the control technology is exceeded, greater losses may result. For example, a flood control dam with a design capacity for a 100-year discharge may serve to generate a false sense of security and to encourage accelerated development of flood-plain lands

such that a flood in excess of the design-discharge will result in higher damages than might have been expected from the same flood in the absence of attempts at flood control [WHITE et al., 1958]. Coastal defenses such as groins and seawalls may have similar consequences in addition to having adverse effects on the amenity value of environment by destroying attractive natural coastlines, interfering with the movement of sand along the beach and thus resulting in locally accelerated erosion, and by obstructing scenic views [BURTON, KATES and SNEAD, 1969]. Indications that seeding hurricanes with silver iodide from aircraft can modify wind and rain intensity quite substantially might similarly lead to a program of hurricane modification before all its ramifications are properly examined. These might include reduction in the rainfall of some areas, and consequent effects on stream regimen, vegetation, river and estuary morphology as well as a wide range of other ecological consequences. Experience in dealing with riverine floods suggests that a major result might also be a rapid expansion of settlement in hazardous sites in coastal and flood-plain areas affected by hurricanes, and that unless controls on land use are simultaneously imposed and enforced it could well be that hurricane modification would have the net effect of increasing the amount of damage or loss of life. In this, as in other cases, the development of the control technology precedes serious consideration about how it might be used. Once developed, the overwhelming urge to put it to use is often irresistable and may well not be accompanied by the social responses that are essential if the technology is to achieve the desired objective.

At the present time, major social concern about the possibility of further earthquakes in the western margins of the North American continent from Mexico to Alaska has encouraged the allocation of considerable research funds and efforts for earthquake prediction and forecasting. Recent experience with accidentally triggered earthquakes has given rise to speculation that earthquake "control" mechanisms may eventually be developed that will relieve stress in the earth's crust in a more gradual manner and thus prevent or reduce the incidence of catastrophic earthquakes. At the same time, little or no effort has gone into consideration of how such control

and forecast technology might be used if it should become available, and in what ways its effects might exacerbate the problem.

In the case of extreme geophysical events such as floods, hurricanes and earthquakes, the dominant strategy has been to apply control technology where it is available and otherwise to allocate funds for research and development towards the end of creating such technology. In both cases this policy is pursued with singularly little attention to ecological perspectives.

The same applies to the policy for dealing with the less violent hazards, for example, the impact of snow on urban areas and on the transportation industry. Here the effort has been concentrated heavily on getting rid of the snow itself as rapidly as possible with little attention to the hidden social costs such as the accelerated depreciation of vehicles and the damage to roadside vegetation associated with the heavy use of salt [BAUMANN and RUSSELL, 1971].

Also in the case of irrigation large expenditures have been made in the face of mounting evidence that this constitutes a serious misallocation of scarce resources - at least in areas such as the southwestern United States where the value of water in urban and industrial uses far outweighs its value in irrigation [WOLLMAN, 1962].

Thus the heavy reliance on control technology can be seen to result in adverse social and ecological consequences, the misallocation of resources, and, over time, the exacerbation of the problem it is designed to solve. The reasons why the technological-fix approach is so popular are woven deeply into the fabric of industrial society. The members of the engineering profession who occupy the driver's seat tend to view themselves as those whose job it is to solve problems for the convenience of their clients or the public, while demanding little or nothing in the way of social accomodation to the changes in environment that they bring about [BARKER, 1972]. The performance of such a role rests on strong public belief in science and technology, and in aggressive attitudes towards Nature. It is also reinforced by the allocation of costs. Large-scale technological solutions usually require large amounts of capital to be invested in large individual increments. The costs thus tend to be

borne by the public at large out of the general revenues rather than by those who directly benefit.

5.1 The Emerging Ecological Consciousness

There are now abundant signs of a significant shift away from the technological fix towards a more ecologically sensitive approach. Industrial societies are becoming much more concerned about the quality of their environment. There is mounting concern about environmental impacts and growing opposition to the degree of social and community disruption often involved in the application of technological solutions. There is also a declining faith in science and technology, and growing sense of alienation among significant sections of the public; attitudes more consistent with ecological balance and harmony with Nature are being more frequently expressed and there is beginning to be a serious questioning of the philosophy of growth for the sake of growth [MISHAN, 1967; MEADOWS et al., 1972] and economic expansion which has been so strongly prevalent in the human history of the past two or three centuries.

The recognized social needs that are being generated by the new ecological consciousness are well in advance of the institutional response. Governments are moving rapidly to pass environmental quality legislation, but have scarcely begun to confront the broader implications for social and economic policy. For example, if the national priorities are seriously shifted away from a high rate of economic growth, the politics of "you never had it so good" and of doubling the standard of living every thirty years, and of the filter-down theory of diffusion of wealth will all be undermined. The less rapidly the national wealth expands, the more insistent will become the demand for equal shares now. This insistence will come from those who are in the relatively disadvantaged sections of the population, who do not now fully share in the private affluence of high mass consumption and who are among those least concerned about the environmental crisis. Further talk of ecological consciousness, zero population growth and lower rates of economic growth among the wealthy without any corresponding recognition of the need for greater equity cannot but

evoke increasing impatience among the disadvantages in individual countries and among the disadvantaged nations of the Third World.

There is little sign, however, that governments and powerful private sector groups like the multi-national corporations intend to do more than reduce pollution in order to permit more growth with less environmental risk. It is still very much a question of more research and development for the creation of an environmentally sensitive technology. No doubt a pollution free car or something close to it can be produced given time and money. Discussions on this problem between the car-producing nations center very heavily on the question of how different national emission standards will affect the terms of international trade, and the strong political support for the so-called polluter-pays principle arises largely from the fear that governmental subsidy for pollution abatement in one country will be a means whereby its products can gain a relative price advantage in the international markets.

Under such circumstances, how can industrial societies move forward towards a realization of the ecological perspective on human affairs? How can the broad social implications of the environmental circumstances of mankind be translated into practical steps and acceptable policy alternatives? If improvement is to be more than skin-deep and if the call for the preservation and enhancement of environmental values is to proceed beyond the cosmetic stage, then some means must be found of taking practical steps. From our experience of research on environmental hazards we see two main avenues. The first is an empirical, decision-making approach permeated by an ecological perspective, which seeks incrementally to broaden the alternative choices available. This is not a course committed to slow improvement. When viewed in a global context it may not be sufficient and it may come too late, but it offers a secure promise of some movement in the desired direction. The second approach, at once less practical, more fundamental and in the long run perhaps more important, is to provide for new human ecological theory. The call here is for the development of theoretical understanding in man-environment interactions and resource and

environmental management. In these areas of human activity empiricism has dominated and we are persuaded that efforts towards the creation of new synthesizing "disciplines" such as environmental science cannot be successfully pursued in the absense of new theoretical frameworks.

5.2 Ecological Empiricism

The adoption of an ecological perspective on environmental hazards leads to a recognition that hazards are not a visitation of malevolent forces upon mankind which must be restricted by attempts to find technological solutions which manipulate Nature. Rather, hazards are seen as a joint product of man and Nature. The level of damage caused by a flood is only in part a function of the magnitude of the discharge, the height reached by the flood waters, their velocity, and so on. Less obviously it is also a function of the use to which the flood-plain land has been put. When the land is in public open space or recreational use the damages are likely to be lower than when dense development of high value property has been placed in the path of the flood waters.

The same is true for all environmental hazards, not simply those that arise in Nature but also those that are normally considered to be of human origin. The distinction between natural and man-made hazards is deeply rooted in the world view which dichotomizes man and Nature. The distinction is not always useful, however, and in the present move towards a new ecological conscience the view of man as a part of Nature is gaining acceptance. In this light, certain commonalities of all hazardous situations begin to emerge. To illustrate this point, consider the apparently fundamental difference between air pollution and drought. One seems to arise from a natural fluctuation in rainfall; the other obviously appears to be created by the emissions from human activities into the atmosphere. In the ecological perspective adopted here a drought is the result of both a climatic fluctuation and the level and types of human activity. Change the grazing pattern on the land, modify the agricultural practices, or replace the crop varieties used with more drought-

resistant types and the significance of the drought is changed. Much the same sort of relationship holds true for air pollution. The quality of the atmosphere over the large cities is both a function of the level of emissions and the capacity of the air to diffuse them according to the degree of turbulence. Anticyclonic conditions producing temperature inversions are as much a cause of air pollution damage as rainfall deficiency is a cause of drought damage. There are other similarities. Air pollution, like drought, is cumulative. It is not a hazard that begins quickly, with a sudden impact, like an earthquake. Nor is it as dramatic as a fish-kill in a sudden discharge of toxic effluents into a stream. Both drought and air pollution build up slowly, having slight effects at first and gradually coming to a peak which can often be dissipated very quickly be a sudden change in the weather.

5.3 A Simplified Model

The joint functioning of man and environment to provide hazards is diagramatically represented in a simplified model (fig. 13.2). The interaction of the human use system and the natural events system has both beneficial and adverse consequences. The beneficial consequences may be referred to as environmental resources and the adverse as hazards. The same interaction process may produce both simultaneously, as when human invasion and development of lands subject to extreme geophysical events puts lives and property at risk. Such invasion may occur due to pressure of population on limited land resources suitable for agriculture, as in the case of the low-lying cyclone-prone lands of the Ganges Brahmaputra delta in Bangladesh, or may result from the perceived comparative advantage of cultivating the richer alluvial soils of the flood-plain in the Mississippi Valley.

Whatever the hazard situation and however it came into being, the common response has been to seek ways of minimizing or eliminating the adverse effects while retaining as much as possible of the useful and beneficial. As described in the opening paragraphs of this section, this has often taken the form of attempts to control Nature. The main thrust has been to seek ways of modifying the natural events

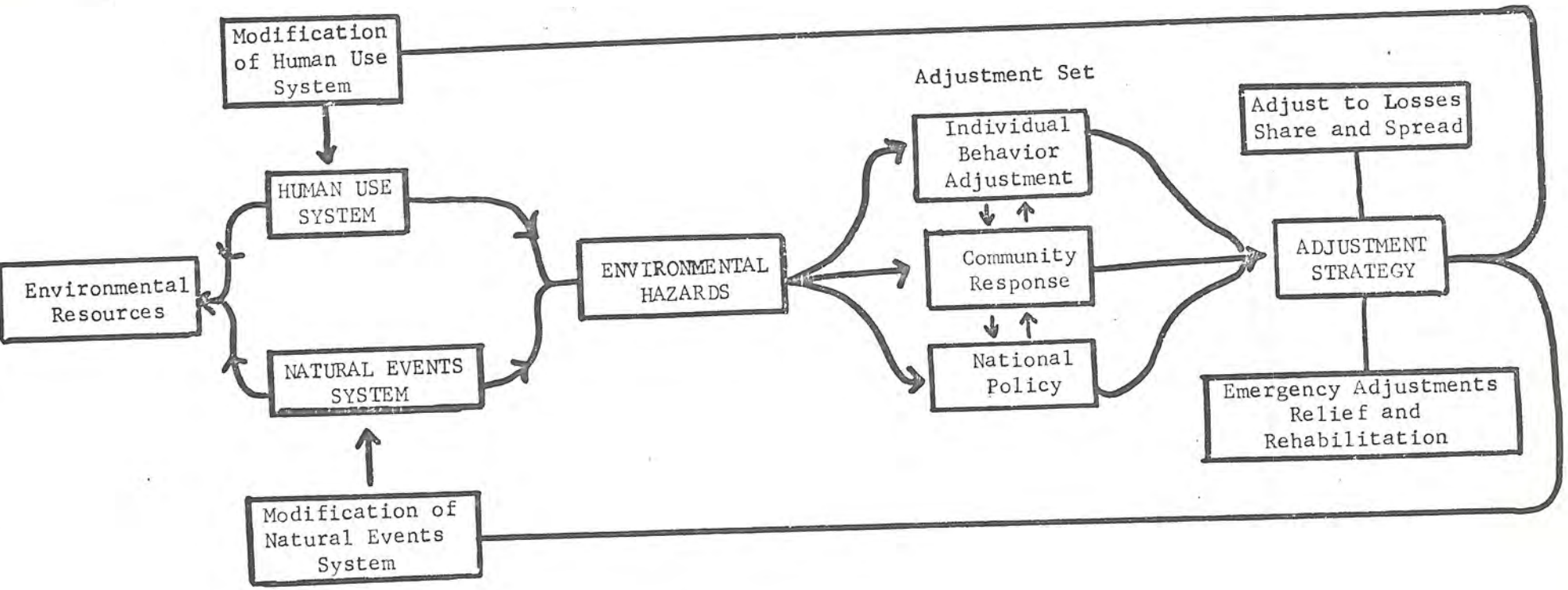


FIGURE 2. A Simplified Model of a Hazard, Response, and Modification System

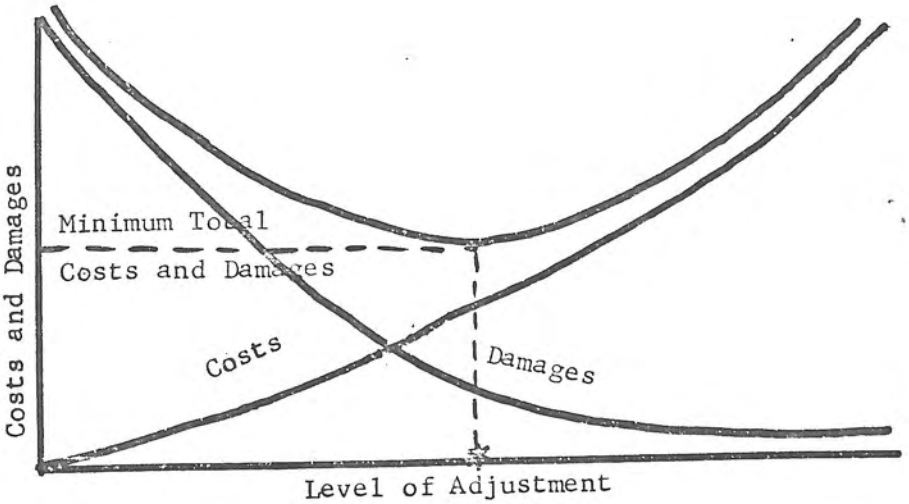
system.

It can be seen that there are other sets of alternatives. Important among these are the numerous ways in which the human use system itself may be modified to reduce the vulnerability of society to environmental hazards. Other possible adjustment sets include the emergency actions of relief, evacuation and rehabilitation and the employment of various social instruments, such as insurance, to share the losses that inevitably occur over a larger number of people, and to spread them over time.

The sorts of alternatives available under each of these four categories are listed in table 13.2. The process of combining and selecting from among these alternatives a judicious mix that will comprise a hazard adjustment strategy does not occur at any centralized decision-making point. The strategy emerges from the adjustment behavior of individuals, from responses at the community level, from national policy and from the interactions among those three.

The net outcome of the adjustment strategy employed is reflected in the aggregate impact of hazards upon society, both in losses and in costs of adjustment. This relationship has been expressed in simple graphic form, as shown in fig. 13.3. The graph shows in theory the point of optimal adjustments towards which adjustment strategy should be aimed.

It seems logical to assume, as many economists have done, that when additional funds are allocated to preventing damage from environmental hazards, that the damage will decrease at least by an equivalent amount. Since highly sophisticated methods of economic analysis have been employed to insure that the benefits (in terms of reduced damages) are always in excess of costs (in terms of hazard control or prevention), it is expected that steady progress should be made towards the optimal point. In fact, the evidence that emerges from geographical research in the ecological tradition has shown that in some cases at least both damage costs and adjustment costs have been rising. Certainly in the case of floods the evidence strongly suggests that the deployment of powerful engineering technology guided by sophisticated economic analysis has resulted in a steady march away from the point of optimal



* Optimal adjustment level

FIGURE 3. Optimal Adjustment Choice

Based on Baumann and Russell, 1971, p. 13.

adjustment. There are indications that the same may now be true for earthquakes, hurricanes and a range of other environmental hazards.

5.4 Extending the Choices Available

The obstacles to any sudden or revolutionary reversal of the situation described are numerous and firm. Established profesional practice is slow to change. The vested interest of intellectuals and whole disciplines, in the accumulated conventional wisdom, is no less than that of political groups and their clients, and, if anyting, is harder to remove. The conventional wisdom cannot be voted out of office every few years. Nor is the lot of an enlightened bureaucrat a happy one. He may well appreciate that there are other neglected alternatives that should be considered, but alone and unaided it is difficult and dangerous to embark upon an adventurous course of proposing untried and therefore suspect innovations.

There is a crucial role to be played for policy-oriented research that can show how other alternatives can be canvassed, subjected to critical appraisals, and employed as part of a management strategy. The task of extending the choices available is slow. It does not offer spectacular results. It does present a clear means whereby an ecological perspective may be used. In giving decision-makers more choice it will help to loosen the constraints that have too long been dominant.

Beyond such important, modest and practical goals lies the need for more fundamental rethinking of man-environment theory. In this paper we have done no more than to propose a marriage between ecological concepts and management approaches. If this union can be established, it might be expected that more consistent policies will emerge across a wide range of environmental issues. Such policies are likely also to be more equitable and to seek the objectives of social justice more vigorously. Above all they would be more sensitive to the role of man in his environment. The change of which we speak is not likely to appear rapidly and were it to appear completely a state of affairs unimagineably close to utopia would exist. There need be little apprehension on this score, for the changes envisaged require not simply different patterns of human behavior but a new self-image of what man is.

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