Mitigating natural disasters: The role of eco-ethics

David Etkin and Ingrid Leman Stefanovic

David Etkin currently serves as Coordinator of the Program on Emergency Management at York University, Toronto, Canada. He worked for Environment Canada from 1977 to 2005, collaborating on teaching and research projects over the last ten years with members of the Institute for Environmental Studies at the University of Toronto. His area of expertise is natural hazards and disasters. He has 55 publications to his credit, 23 of which are in peer-reviewed journals. He has participated in several international projects dealing with disaster studies, and was Principal Investigator on the Canadian Natural Hazards Project. Ingrid Leman Stefanovic is Director, Centre for Environment, at the University of Toronto and a former member of the Executive Council of the World Society for Ekistics. Her area of teaching and research is environmental philosophy, with a special interest in how values and perceptions affect environmental decision making. Her most recent book is entitled Safeguarding Our Common Future: Rethinking Sustainable Development *(SUNY, 2000). Contact Professor Stefanovic at Centre for Environment, University of Toronto, 33 Willcocks Street, Toronto, Ontario. M5S 3E8 or email ingrid.stefanovic@utoronto.ca. The text that follows is a slightly edited version of a paper published in* Mitigation and Adaptation Strategies for Global Change, *vol. 10, pp. 467-490 (Springer, 2005).*

Introduction

Disasters are about human misery. They are about unravelling and reconstruction. Understanding them means more than developing conceptual frameworks, drawing diagrams and calculating numbers. It means glancing into the tragedy that strikes people's lives. Few have expressed this more eloquently than Susanna Hoffman (1998) after her home, along with 3,356 others, was destroyed in the Oakland firestorm of 1991.

> *"I had no salt. By this I mean I had no salt to put upon my food, and also that I had no salt left for tears. My weeping depleted every grain from my being.*
> *I had no thread. By this I mean I had no thread to stitch my daughter's hem, and also I lost the thread of my life....*
> *I had no numbers. I had lost all the addresses and phone numbers of everyone I knew or had ever known... I lost both my connections and the equations that lead to opportunity.*
> *I had no paper, no sheets, no warm, wooly sweater, no lights... but also no lightness. No joy...*
> *... it was a rapid introduction into deconstructionism.*
> *While standing amid the rubble of my home, I also stood amid the rubble of a social and cultural system."*

Whether or not one chooses to explicitly address human impacts in one's work, it is important to keep in mind that our decisions have important consequences, and that we must not divorce disaster prevention from ethics, culture, or the broader social and environmental systems that sustain us. Recent work has discussed natural disasters within the context of sustainable development and holistic thinking (MILETI, 1999). This paper is an attempt to build upon that discussion, by considering where mitigation lies within the broader conceptual geography of our disaster experience.

We address several main themes in the following pages. Following our clarification of some central terms, we identify certain problems arising from current, sectoral approaches to mitigation. Recognizing the limits of these strategies and the need for a broader perspective, we then put forward some tentative suggestions for a holistic eco-ethical understanding of natural disasters that situates the issue of mitigation within a more comprehensive framework.

In presenting mitigation of disaster issues within an eco-ethical framework, this paper emphasizes the interconnectedness between humans and nature, and how a dysfunctional relationship can contribute towards vulnerability. The importance of considering this issue from an interdisciplinary perspective is also critical. Values affect the decisions people make to mitigate risk and, for this reason, differing values can lead to varying degrees of vulnerability. Economist William Reese wrote "*for sustainable development ... the need is more for appropriate philosophy than for appropriate technology*" (noted in STEFANOVIC, 2000). This paper attempts to echo that sentiment.

Clarifying terminology

We would like to begin by clarifying our understanding of some key terms employed in this paper. Of primary importance is our interpretation of the very concept of **mitigation**, which we define as sustained actions to reduce or eliminate the long-term impacts and risks associated with natural and human-induced disasters.

Mitigation actions can be a blend of policies, educational programs, structures (such as dams), design of resistant or resilient systems, retrofitting (such as reinforcing buildings to ground shaking), or land use planning (such as restricting development within flood plains). As such, these actions affect both the social and natural realms. The particular choice of strategies and blend of approaches depends upon a variety of factors, including world view, ethics, taken-for-granted assumptions, resources, capacity to adapt, disaster history and socio-political institutions.

Generally, mitigation occurs through activities that

- reduce risk, or
- transfer/share risk.

Risk reduction can be accomplished by

• modifying the hazard, or
• reducing vulnerability.

Studies of some hazard reduction programs, such as weather modification (including hail suppression), have either had mixed results or not been encouraging. In fact the American Meteorological Society policy statement on planned and inadvertent weather modification, dated October 2, 1998, says "*There is no sound physical hypothesis for the modification of hurricanes, tornadoes, or damaging winds in general*" (WMO, 1995; NOAA, 2003). Other strategies, such as floodways, dykes, land use planning, revegetation of slopes and irrigation can be very effective, and have been widely used.[1]

Within Canada, transferring risk is mainly achieved through:

• insurance (both private and government sponsored, such as crop insurance) and
• government disaster assistance programs.

Internationally, the World Bank and International Monetary Fund (IMF) provide grants and loans to assist developing countries recover from disasters.

Another key term employed in this paper is **ecology** (including its variation within eco-ethical) – a concept that emerged originally from the work of German biologist, Ernst Haeckel, in the 1860s. Haeckel recognized that the etymology of the word leads to the Greek *oikos*, which means house, habitation or dwelling place and *logos*, meaning the articulation or "study of." Ecology, then, is the study of the relationships between organisms and their home environments.[2] While the science of ecology has interpreted these relations in diverse ways, from community to energy models, our reliance upon the term is meant simply to emphasize that individual, living entities (including human beings) cannot exist in isolation from their surrounding habitats.[3] Indeed, there is a case to be made that these linkages are so fundamental as to be a necessary condition of human existence in the first place (STEFANOVIC, 2000). In this vein, we argue that natural disasters occur because of the interdependent relationship between our human species, their dwelling places and the natural world, and that it makes sense to understand this relationship within a broad, eco-ethical framework.

Moreover, when we refer to the "eco-ethical," we are seeking to acknowledge that a genuinely interdisciplinary ecology is also one that invokes questions about tacit value judgments, taken for granted assumptions and worldviews that shape our outlooks on life. The ancient Greeks recognized that *êthos* refers to our fundamental ways of dwelling in the world. Recognizing our rightful place and a fitting attunement between what *is* the case and what *ought* to be the case becomes a central task in critical thinking about disaster mitigation policy.

● **Vulnerability** is used in this paper to refer to the propensity to suffer some degree of loss (e.g. injury, death, and damages) from a hazardous event. This depends upon coping capacity, relative to potential impact. For example, a supertanker is not vulnerable to 2 m waves, though a rowboat certainly is. There are a number of different types of vulnerability that are traditionally addressed:

- physical (such as living in a location exposed to hazards);
- personal (such as age);
- cultural (such as how risks are perceived, and responded to);
- socio-political (such as no or limited accessibility to information, limited control over resource allocation and pertinent decisions);
- structural (such as poorly built, or insufficiently strong or resilient systems);
- economic (such as wealth distribution, economic diversity);
- institutional, both regulatory and jurisdictional (such as enforcement of standards and codes, type of governance); and,
- psychological (dread, avoidance, denial).

It may make sense to add another vulnerability classification – eco-ethical, which occurs when our value system leads to the loss of resilience in the natural ecosystem, which then in turn results in increased hazards or greater human vulnerabilities. In practice, these vulnerabilities are intertwined. Particularly, decisions that determine how and where we build are largely determined by our culture, value systems, economy and institutions.

● Approaches to vulnerability reduction tend to focus on increasing **resistance** (by changing design criteria to protect against more extreme events) or by increasing **resilience** (by creating the capacity to "bounce back" more quickly and easily after a damaging event occurs). The former reduces the number of damaging events, the latter, given that a damaging event occurs, reduces its impact.

The nature and characteristics of resilient ecosystems is discussed at length in Holling and Gunderson (2002). They differentiate between engineering resilience, which tries to maintain an equilibrium near a stable state, and ecosystem resilience, which is measured by the size of a disturbance that can be absorbed before a system changes its structure and flips into a different state. The former emphasized command and control, predictability and efficiency; the latter a set of conditions that allow for adaptive decision making. They argue (and we concur) that it is the second definition of resilience that is needed for a sustainable relationship between people and nature. Organizations that optimize economic efficiency, for example, do so at the price of losing ecosystem resilience.

● Finally, it is our contention that, at the present time, we easily tend to slip into a reductionist, **positivist** framework for environmental decision making. Reductionism assumes that complex problems are best analyzed when they are broken down into smaller, component parts. When such sectoral reduction occurs, a positivist epistemology tends to support the view that reality consists of those entities that can be empirically seen, touched, felt, measured and "positively" quantified (STEFANOVIC, 2000). While such an approach boasts many accomplishments, it fails to adequately account for less obvious, intangible (and therefore, difficult to measure) *relations between* entities within the holistic context that ecology does address. In the following, we consider some of the problems associated with employing a reductionist, positivist framework for considering issues of disaster mitigation.

Problems with positivist, human-centered approaches to mitigation

In a scientific era, the tendency in the Western world has been to try to understand, as well as manage and control, the complexities of nature through sectoral, reductionist analysis. Frequently, such an approach operates within an "anthropocentric" framework, where humans are implicitly viewed as being above nature, and nature itself is viewed as an unlimited inventory of resources for human consumption and control (STEFANOVIC, 2000). Within such a framework, the natural environment is a collection of resources exploited by society for sustenance and growth, principally from an *economic* perspective.

The environment is also present as a source of risk, when natural extremes create temporary conditions that lie beyond the normal coping ranges of society. Hopefully, one builds social/economic/physical environments with natural risks in mind such that vulnerability is minimized (for example, using building codes or other safety standards), but when these natural hazards do trigger an existing social vulnerability, natural disasters occur.

Society's coping range is defined in part through a series of sectoral design decisions related to infrastructure, lifelines of communication or transportation and land use practices. Commonly, systems are designed to be resistant to some level of probability, often defined by a return period. This construct, used to define acceptable risk, has often had the net, cumulative, long-term effect of increasing the costs of natural disasters (MILETI, 1999). The positivist rests assured that measurements of probability have been quantified and regulated. At the same time, simply because a design provides safety against a 100 year flood (for example) does not mean that a community is safe, as the vagaries of nature frequently will create a flood of greater proportions. Risk is increased when people or communities act as if safety has been assured, when in fact it has not.

We mistakenly believe that our quantificational systems are objective, scientifically proven measures, but nature does not always respect our human assessments of boundaries. For example, where urban development occurs and natural infiltration of rainwater into the ground is greatly reduced, storm sewers are used to limit flooding. However, extremes sometimes occur beyond the design of the sewer system and, frequently, few natural buffers exist to control flooding. When a flood does occur, the costs are unexpected. By such actions, society has not been engaged in "wise use" as Gilbert White would say and ultimately has transferred risk to future generations (MILETI, 1999).

Generally, in risk assessment, we tend to rely upon quantificational methods of analysis but increasingly such approaches are seen to be limited in scope. Often, we concentrate upon identifying "objective" probabilities of failures of technical systems at the expense of incorporating non-quantifiable probabilities of human error, for instance. Conrad Brunk (1995, p. 160) questions these priorities, suggesting that non-quantifiable elements can be crucial. "Just what was the 'objective' probability," he asks, "that the maintenance crew at Three Mile Island would forget to re-open the valves in the auxiliary cooling system after routine maintenance (the major contributory factor in the accident)?" Try as we might to capture all eventualities within our reductionist frameworks, the human factor is one example of an element that exceeds positivist measures in any definitive sense.

It is beginning to be evident that many environmental risks exceed simple, mathematical measures. Is risk to be measured simply in terms of the number of human lives lost, diagnosed illnesses or GDP? New concepts are emerging that cannot be easily quantified and yet are seen as valuable. Examples include notions of integrity, resiliency, sustainability and ecosystem health. Brunk (1995, p. 157) reminds us that "because probabilistic risk assessment is a quantitative methodology, whose output is only as reliable as the quantitative precision of the data input into its algorithms, it is strongly biased in favor of identifying only those values 'at risk' that are easily quantifiable. These are not necessarily the values most important to the general public. Among the values excluded, for example, are those of personal and collective autonomy, matters of fairness in the distribution of risks and benefits, as well as cultural, religious and 'metaphysical' values."

Brian Wynne, Director of the Centre for the Study of Environmental Change in Lancaster, U.K., echoes these sentiments when he points out that "what can actually be measured frequently dictates the structure of the resulting knowledge" (1992, p. 113). Certainly, averaging, standardization and aggregation are necessary components in quantifying risk. Nevertheless, "the fact that this is necessary and justified does not alter the point that it imposes man-made intellectual closure around entities which are more open-ended than the resulting models suggest." (WYNNE, 1992, p. 113).

To quantify and assess risks, then, in a narrow, reductionist manner is to jeopardize significant issues that cannot fit the model but nevertheless are important to the broader public and do substantially affect mitigation efforts. Real social, as well as ecological impacts, may be excluded in such a system that neglects to address non-quantifiable concerns.

In fact, reductionist paradigms very frequently lead to an overemphasis on risk in the first place. Mary O'Brien (2000) questions this emphasis, by providing numerous examples to show how current, narrow approaches to risk assessment – aiming at impartiality – have led, nonetheless, to governments and industry sanctioning the widespread contamination of air and the poisoning of wildlife and groundwater. She offers another decision-making technique that she calls "alternatives assessment" that is broader in scope than traditional risk assessments. Instead of attempting to unsuccessfully quantify risks and thereby generate oversimplified predictions, O'Brien argues from the premise that it is simply unacceptable to harm human or ecological health, if there are reasonable alternatives. Through broader public dialogue, more informed decisions can emerge from a holistic framework that seeks to minimize ecological damage while achieving social goals.

In a similar vein, Wynne (1992, p. 114) argues that other forms of uncertainty than risk are at play in hazardous situations, such as indeterminacy and ignorance, for example, where we may not know what we do not know and causal chains remain open and unsure. Many hazards are basically indeterminate: the dangerous decrease in stratospheric ozone in the earth's atmosphere was not recognized until it had actually occurred. We are asking the impossible from scientific risk assessment, if we expect "objective" analysis of previously unacknowledged possibilities – which is not to say that we ought not to assess risk, but rather that we should simply recognize the limits of the process, and perhaps look to supplement these methods of analysis with other, less conventional approaches.

When we ignore these broader considerations of uncertainty, risk is potentially increased in two ways:

- firstly, vulnerability is increased due to a "command and control" approach that ultimately fails (HOLLING and GUNDERSON, 2002); and,
- secondly, some hazards increase as a result of environmental degradation resulting from a consideration of nature as an unlimited resource that can be used as a tool to fuel economic growth, the use of which lacks consequences.

This latter approach has resulted in, for example, depleted ozone layers, deforestation, desertification and climate change. The underlying issue is the assumption that as a result of environmental degradation, systems will not fail, or are not vulnerable to feedbacks resulting from technological adjustments.

Such a positivist, engineering approach to mitigation is embedded in a belief that nature is predictable and controllable by human beings, the roots of which lie in the 17th and 18th century paradigms of Newton, Descartes and other rationalist thinkers, and can be traced back even to Plato (STEFANOVIC, 2000). In part, this approach assumes that science can understand, predict and perfectly engineer the natural world. It is also based on a belief that it is humankind's natural right to control nature, a perspective that places us "above" the natural world (DEVALL and SESSIONS, 1985).

Such anthropocentric value systems that favor human beings over the natural world have deep historical roots in our Western, metaphysical tradition. Current mitigation strategies often reflect those human-centered normative theories. Consider, for example, the construction of dams and dykes. These engineered structures are intended to alter and control hydrological systems, expressly for human purposes of flood control and power generation at the expense of preserving ecological balance.

Examples of such anthropocentric interventions include the Three Gorges dam in China, which may cost more than any other construction project in history. The dam requires the resettlement of many communities and "would alter the current ecosystem and threaten the habitats of various endangered species of fish, waterfowl and other animals, and ...would necessitate extensive logging in the area and erode much of the coastline" (CHINA ONLINE, 2003). Likewise the W.A.C Bennett dam in British Columbia, Canada, has caused a significant drop in water flow to the Peace-Athabaska delta, one of the largest freshwater deltas in the world (ENVIRONMENT CANADA, 2003).

At times, such interventions have placed environmentalist groups at odds with the proponents of these systems. Failure of technological systems designed to protect people and their built environment can occur in two ways, one being a natural trigger beyond the design criteria of the system, and the other being failure due to such things as lack of maintenance, quality of construction issues or human error. The 1996 Saguenay flood in Quebec is a spectacular example of such system failure, and of the limitations of complete human control over nature, despite engineering ingenuity. A complex system comprised of 45 watercourses and about 2,000 flood control structures owned by 25 different organizations, the defence mechanisms were unable to deal with the extreme rainfall of July 19-20, 1996, and the Saguenay River broke through an earthen dam and created a cascading wave of destruction downstream along its natural hydrological pathways.

The nature of urban development in Canada also reflects this anthropocentric, technocratic bias. Natural drainage systems are eliminated and replaced with impermeable paving and storm sewers. The result has been an increase in urban floods (DORE, 2003). A more ecological approach includes rooftop gardens, increased respect for natural floodways and paving designs that allow infiltration to reduce the urban flood problem and also help curtail urban air pollution.

Anthropocentric views are reflected in several aspects of the recovery process as well. Take the examples of reconstruction using disaster financial assistance arrangement (DFAA) and private insurance. Both of these programs fund recovery after disasters, and can either increase or reduce vulnerability to future hazards, depending upon how they are implemented.

DFAA is funded using tax dollars and, in many respects, assumes a utilitarian ethic. All Canadians contribute towards this funding mechanism. The assumption is that financial assistance for community recovery ensures the overall greater good for Canada or Canadians. This redistribution of wealth is applied using the precept that greater amounts of aid should go towards those who have lost the most, up to some maximum amount. There may well be some people in far greater need who get no or little assistance (the homeless for example), but this particular application of the greatest good is based upon equal distribution of opportunity in proportion to incurred loss (in the sense that all those who suffered from the disaster should have an opportunity for maximum possible aid), as opposed to the uniform distribution of welfare or resources.

At the same time, the disaster financial assistance program also motivates us to assist those who have suffered through no fault of their own. Canadians feel obliged to help those in need and, in some sense, the assumption is also that citizens have an individual right to expect some aid from governments during their times of need. This right is not unlike the perceived right to health care that, supporters claim, ought to be available for all Canadians, no matter their income level.

While this kind of social aid is crucial to the recovery process, it has been criticized from a number of perspectives that can be traced back to conflicting moral claims. For instance, one criticism arises within a concern of who carries the burden of responsibility for recovery costs. A utilitarian ethic supports the notion that financial assistance should be distributed to advance the maximum possible good for the greatest number. In this case, one concludes that governments ought to provide assistance for disaster recovery to the maximum number of those who have been affected by a disaster.

On the other hand, does this blanket obligation to assist in recovery apply to all equally? Do our individual rights and freedoms as Canadians also include the right to choose to live in risk-prone areas? Some people who bought properties in flood plains zoned for residential use by a municipality may not have had knowledge that they did so. However, it is a different case when victims of a disaster are perceived as knowingly and willingly having accepted undue risk by living in hazardous zones, without taking reasonable risk-reduction actions (such as flood proofing or buying extra insurance). Then, there is a strong argument to be made that the misery is self-inflicted, and the responsibility for recovery remains with the afflicted community and individuals. This is similar to the argument that smokers should pay more for health care. While we may, as utilitarians, wish to maximize the greatest good for the greatest number, do all members of that "greatest number" have equal rights to compensation?

Indeed, DFAA programs can be criticized, precisely because they shift the burden of responsibility to governments who will eventually cover the costs and, therefore, allow citizens to engage in more risk-prone activities. Disaster assistance tends to create a culture of complacency (or even dependence). Such a culture, when it occurs, increases vulnerability and raises the question of whether disaster recovery initiatives should more properly be assumed by individual property owners, and in a more direct manner.

The same dilemmas apply when it comes to insurance. In the U.S., a government sponsored National Flood Insurance Program (NFIP) exists. One of the founders of the program, Gilbert White, has noted that the net effect of the program was to encourage development within flood plains, thereby increasing flood damage and the overall vulnerability of society. "The net effect ... of practicing such a national policy – for which now about 30% of the property owners in floodplains these days buy insurance – may be counter-productive, and the result is an increase in annual losses from floods rather than a decrease. Rather than promoting wise use of floodplains, it might enforce ... unwise use" (WHITE, 1999).

This view has also been supported in a recent paper by Larson and Plasencia (2001) who state that "annual flood losses in the United States continue to worsen in spite of 75 years of federal flood control and 30 years of the National Flood Insurance Program." In the U.K., a similar situation seems to exist. David Crichton (personal communication, March, 2002) noted that the "1961 UK insurance guarantee ... has had the effect that in many ways flood insurance has been taken for granted by government, planners, and developers, and many housing developments have taken place since 1961 in high flood hazard areas."

This kind of risk-prone behavior occurs because individuals and communities view the consequences of their actions upon the environment as lying elsewhere. Instead of seeing their conduct in terms of broader, eco-ethical impact, they choose to either ignore the risk or shift responsibilities for their actions or inactions to other agencies. At least one Canadian study supports this view, that being the Michigan vs. Ontario flood damage comparison (BROWN et al., 1997). In this study, it was found that a set of storms affecting both areas resulted in costs of about US$500 million in Michigan, but less than $0.5 million CAD in Ontario, as a result of greater development in Michigan flood plains. This difference results from different cultures, the former that allowed flood plain development (with some restrictions with respect to the purchase of flood insurance), and the latter that restricted it. Within Ontario, development within flood plains was actively discouraged and prohibited, with planning and flood control done on a watershed basis through conservation authorities. The U.S. relied largely upon the National Flood Insurance Program (NFIP), which was based upon the theory that "if property owners are required to purchase flood insurance at actuarial rates that reflect flood risk, and if risk is reduced through regulations that require the elevation of new construction in flood plains and avoidance of development in floodways, the added costs of construction in the floodplain should dissuade uneconomic uses" (BURBY, 2001).

In practice, the NFIP suffered from a number of deficiencies, including incomplete flood hazard identification, flawed methods and poor marked penetration. Burby (2001) noted that the NFIP may even have stimulated building within the 100 year floodplain. Also, even if buildings within flood plains were protected against the 100-year flood, they would certainly be vulnerable to events of greater severity, which could account for increased flood losses relative to a strategy prohibiting floodplain development. Though our entrenched beliefs in property rights may also lead some to conclude that we have the right to build in risky areas, the reality is that some portion of the costs for such actions are inevitably borne by society at large and thereby increase overall social and ecological vulnerability.

Nevertheless, many do believe that individuals at risk have the responsibility to purchase insurance to protect their property so that recovery can occur, should disaster strike. Those who do not buy insurance have gained the benefit of not paying premiums, and have made a choice to assume the risk that goes with that benefit. It follows that they should accept the cost of their decision, in the event of calamity.

The issue becomes complicated, however, when one realizes that the ability to buy insurance varies with the socio-economic stratum of the individual or community and, therefore, recovery relying upon this process tends to maintain or accentuate socio-economic ramps. Reliance upon this method alone discriminates against the less wealthy classes of society, who are presumed to contribute towards the greater social good, but who may not be able to purchase insurance, or sufficient insurance. This is one of the reasons that societies with unequal distributions of wealth are considered to be more vulnerable to natural disasters. From a utilitarian perspective, insurance is a useful but insufficient tool for disaster recovery.

In fact, it must be remembered that not all hazards are insurable (for instance, residential flood insurance is not available in Canada). In practice, the purchase of disaster insurance is not always encouraged, since it is often more politically expedient to assist the recovery of victims whether they have purchased insurance policies or not. Ecological damage to wildlife and their surrounding habitats is rarely considered in such moments, and yet no amount of insurance can protect them from hazards.

While insurance and DFAA recovery programs have been designed to reduce the impact of disasters, here in Canada as well as in many other parts of the world, they have been criticized for reconstructing vulnerability. One of the reasons for this is that these programs are typically based upon the principle of returning a community to its pre-disaster state. This policy may have something to do with an enduring sense of place identity on behalf of residents. If that location remains particularly vulnerable to hazards, then recovery has simply made another future disaster inevitable.

Both types of programs require constraints to discourage risk-taking behavior where it is not appropriate, and to encourage risk-reduction activities. Incentives through reduced insurance premiums have been shown to be one good tool (e.g. the Federal Emergency Management Agency [FEMA] Project Impact uses a "carrot" approach that rewards risk reduction activities). Refusing disaster aid to those who have taken excessive risks (the "stick" approach) might also be a useful but harsh tool though, historically, the political response to this has often been to not enforce it. Refusing aid to disaster victims, especially in media-intensive events, is not politically expedient and runs against an accepted utilitarian ethic of promoting the greater good. As well, people are likely to discount risks associated with rare, extreme events, making the stick approach not as effective as an agent of change as the carrot one.[4]

No matter what kind of insurance policy is put in place, as a society we must begin to realize that neither technocratic, positivist solutions nor juggling different forms of compensation are going to the root of the problem. The fact is that when developing in flood plains, for example, we are acting *in opposition to* existing natural states. To be sure, we need not passively submit to nature's constraints but, at the same time, neither must we act in total disregard of pre-existing natural conditions. Whether we feel justified in damming rivers or fine-tuning insurance policies, moving beyond narrow, egoistic, anthropocentric perspectives opens up different possibilities for mitigation activities. That means that even if a municipality is legally empowered to develop in flood plains, and even if an insurance policy is put into place to compensate potential victims, we must continue to ask questions such as: what kind of compensation are we extending to ecosystems and other non-living victims of disastrous planning? And what kind of imbalances are we creating by refusing to find a proper eco-ethical "fit" between our human actions and the needs and constraints of the natural world?

In an effort to reduce risk, it is important to clarify ethical assumptions and to resolve competing claims (STEFANOVIC, 2003). As the examples above indicate, many value judgments underlying current discussions of mitigation are rooted in a predominantly human-centered ethical paradigm that aims to address such issues as human rights, the greatest good for the greatest number of human beings and, ultimately, risk to human well-being.

In the following, we shall consider expanding these parameters to include broader ecological communities within the dialogue of ethical obligations.

The need for a broader, eco-ethical perspective

While reductionist, anthropocentric values are persistent, the development of chaos theory, our experience with the rising costs and impacts of disasters, numerous case studies that show the negative impact of decision making that excluded the environment, and the development of ecological models that place humans within, not outside, the natural environment, have given impetus to a different paradigm. Natural disasters must be considered within the framework of human ecology, where a complex set of interdependencies exist between society and its natural environment.

We might glean some lessons from Aboriginal traditional ecological knowledge (often abbreviated as TK or, more ironically, TEK). According to traditional Native American teachings, the world exists as an intricate balance of parts to a whole, and humans must recognize this balance in order to maintain ecological health (BOOTH et al., 1993, p. 523; CALICOTT, 1994). Environment Canada's *Science and the Environment Bulletin* (2002, p. 1) rightly points out that, "over centuries of living in harmony with their surroundings, Aboriginal peoples in Canada have gained a deep understanding of the complex way in which the components of our environment are interconnected." A number of resource management boards, commissions and legal agreements, such as the Convention on Biological Diversity, explicitly recognize that Aboriginal traditional knowledge emerges from a holistic view of the world, encompassing biophysical, social, cultural and spiritual awareness and arises from a perception of "humans as an intimate part of [the environment] rather than as external observers or controllers" (ENVIRONMENT CANADA, 2002, p. 1). This recognition is passed on orally through songs and stories: the Haudenosaunee Creation Story, for instance, "tells us of the great relationships within this world and our relationships, as human beings, with the rest of Creation" (HAUDENOSAUNEE ENVIRONMENTAL TASK FORCE, 1992, p. 2).

While the term "traditional ecological knowledge" only came into widespread use in the 1980s and was often dismissed as mere anecdote, governments and policy makers are increasingly coming to a recognition of the importance of indigenous knowledge in public policy. "Time-tested and wise," traditional aboriginal approaches to the land provide qualitative information about a variety of natural phenomena (BERKES, 1999, p. 9).

Environment Canada researchers and officials have organized several Elder/scientist retreats to share their knowledge and learn from one another (ENVIRONMENT CANADA, 2002, p. 2ff). Projects across the country bring together government scientists and indigenous peoples to profit from one another's knowledge. Examples include a project in the North, where the Vuntut Gwich'in people – hunters and trappers from the Yukon – advised biologists of dropped water levels in more than 2,000 shallow lakes and ponds in the Old Crow Flats. Upon satellite investigation, supplemented with aerial photos, scientists were able to confirm that lakes are either drying up or draining "catastrophically" – likely one more indicator of climate change (ENVIRONMENT CANADA, 2002, p. 3).

The Government of Canada concludes that these sorts of collaborative initiatives between scientific research and traditional aboriginal knowledge only "improves our understanding of the many and complex influences affecting our environment and the steps we must take to ensure sustainability for future generations" (ENVIRONMENT CANADA, 2002, p. 3). One wonders, for instance, whether an aboriginal reverence of the land as sacred, could find much justification of large scale damming of waterways in the first place.

Aboriginal societies are no longer alone, of course, in recognizing the importance of a holistic perspective on environmental issues. A significant, interdisciplinary approach to urban planning and, in some specific cases, to natural hazards assessment emerged some years ago through work in Ekistics – the science of human settlements. Leading back to the same etymological root as ecology, *oikos,* interdisciplinary Ekistic research has shown that a series of elements and functions define every human settlement at all scales, from individual dwelling to an urbanized world (DOXIADIS, 1968). The elements include:

- nature;
- human beings;
- society;
- buildings and physical infrastructure; and,
- communication and information networks.

In addition, social, cultural, economic, regulatory, technological and biological functions are virtually always present in any human settlement. Different underlying worldviews and attitudes affect their specific manifestation and characteristics. Needless to say, these elements and functions interrelate and any disaster mitigation policy must recognize both the scope of each item individually, as well as the complexity generated through the synergistic relations exhibited in our human settlements. We can no longer address simply one item on the list but must aim towards a genuine interdisciplinary approach to disaster mitigation and recovery programs in order to generate more resilient communities.

James Mitchell (1999, p. 40) has recently pointed out our serious failure as a society "to treat natural hazards as complex systems with many components that often require simultaneous attention. We tinker with one or another aspect of these systems when what is required are system-wide strategies." Mitchell concludes that there has been a growing recognition that "broader interpretive frameworks are necessary – frameworks that incorporate both society and nature and a variety of contextual variables" (1999, p. 43).

Ekisticians have made attempts some time ago to generate such comprehensive interpretive frameworks. Ovsei Gelman and Santiago Macias from the Mexican National Autonomous University (1984, p. 509) presented some preliminary work toward a conceptual framework for interdisciplinary disaster research that would offer the methods and terminology "with which to facilitate the integration of various studies and the consolidation of all related efforts...to safeguard and guarantee the continuity of socioeconomic development at the community, regional and national scales."

In a similar vein, Canadian architect and planner, Alexander B. Leman (1980) generated an interdisciplinary matrix that plotted the impacts of disasters upon the Ekistic elements and functions. Not unlike environmental impact assessments, this model served as a tool for identifying patterns and trends, as well as providing a global overview of priorities for disaster mitigation.

Such an interdisciplinary tool might also help to highlight strengths and weaknesses of mitigation policies. Consider, for example, how plotting such a grid may indicate how a narrow focus on technological solutions may have ignored local social and cultural conditions, thereby decreasing a community's overall resiliency. The very success of some government disaster assistance programs is a debated topic, with some aid agencies such as the Red Cross claiming that the World Bank and IMF have historically contributed to the disaster cycle, due to their particular, narrow philosophical/cultural approaches (IFRC, 2001). These approaches, which typically have been short term, ignored local cultures, emphasizing technologically-based solutions. Increasing debt loads have at times reduced local resiliency and led to cultures of dependency. Both the World Bank and IMF organizations have apparently recognized these issues, and are increasingly advocating broader-based solutions that recognize local capacity building (WORLD BANK, 2002; IMF, 2003). By identifying impacts through an interdisciplinary model, there is a chance that a broader net is cast over a wider set of human settlement elements and functions in our policy development.

As noted earlier in this paper, reducing vulnerability can be accomplished by increasing resistance or resilience (i.e. building fail-safe, as compared to safe-fail). Both are important. However, it is more common for resistance to be emphasized. For this reason, the following discussion focuses on the resiliency aspect of vulnerability, where more opportunities seem likely.

"Building resilient communities" is a phrase that one sees more and more often in the disaster mitigation literature. This makes good sense, but a clear idea of what resilience means is needed. Webster's dictionary defines it as "recovering readily." What does it take for this to occur?

There are two sides to the issue,

- the first relating to the extent and nature of damage inflicted upon a community; and,
- the second related to capacity (i.e. having the resources available for rebuilding).

Canada has done a good job, overall, on the second (above). A relatively wealthy country with a well-entrenched insurance culture, strong technical capabilities and a disaster assistance program, it has the capacity to recover from many severe disasters. No doubt it could be improved, but greater opportunities to increase the resilience of our communities seem likely to exist within the first category; thus an emphasis on mitigation as opposed to recovery. This view has been supported by Senator Terrance R. Stratton, Chair of the Subcommittee on Canada's Emergency and Disaster Preparedness. He noted in 1999 that "we react very well, but we do not mitigate or plan properly for these events – we react to these events. I believe we must go through the process to find out how we can mitigate these events and minimize the damage to human lives. Fundamentally, that is what it is all about. We must do some proper planning."

Within this context, there are two main problems leading to a lack of resilience:

- The first is that society is obsessed with short-term economic efficiency (which can only be achieved with a loss of resilience, such as eliminating system redundancy or capacity). Being economically efficient requires minimizing costs and maximizing benefits. System resilience can only be achieved at some cost, examples being the maintenance of secondary backup systems to essential services, and maintaining stockpiles of goods (as compared to systems reliant upon complicated transportation systems). For example, Britain was hit by a foot and mouth disease catastrophe in 2001. The disease was able to spread so rapidly because the system that transported cattle created fast disease vectors, as compared to a more conservative but perhaps more expensive one.

- The second problem leading to a lack of resilience is that we do not incorporate the risk of rare high-consequence events appropriately into design (ETKIN, 1999). For example, had the transmission towers that failed during the 1998 Quebec and Ontario ice storm been designed with safe fail properties (such as with collapsible arms, so that the entire tower did not fail) then recovery would have been faster and less expensive. Making systems or structures more resistant does not eliminate or reduce the individual cost of disasters; it makes them less frequent. Designing resilient systems can truly lessen the impact of a disaster.

Building resilience into our designs and systems requires the assumption of failure – something we are often loathe to do, but that experience has shown to be a reality of our existence. We have grown up in a culture that believes humankind can control nature and, while we are successful in this human undertaking in general, the episodic occurrence of extremes beyond our coping range demonstrates the falsity of this conviction. The concept of resilience applies not only to engineered structures, but equally to ecosystems, which act as important buffers to natural hazards.

In fact, integrating technological innovations with environmental, social, cultural and economic concerns opens up new possibilities for disaster mitigation. A prime example emerges from research conducted by Brad Bass at the University of Toronto (personal communication, 2002). Studies have shown that green roofs (rooftop gardens) can have a similar storage capacity for rainwater as compared to large underground storage tanks, used as a safety valve to reduce flooding when sewer systems are overwhelmed. The green roofs cost less, can reduce the storm surges more effectively than storage tanks, and offer a series of co-benefits, including energy efficiency for buildings as a result of reduced cooling costs and improved urban air quality, as well as non-quantifiable benefits related to an improved urban landscape. By "greening mitigation," numerous benefits accrue to society.

Generating solutions requires not only answering, but also asking the right questions. Building resilience requires asking a greater variety of questions, including "under what circumstances will this 'widget or whatever' fail?" "are the consequences of failure acceptable?" and "what can be done to minimize the consequences of failure, when it occurs?"

Though the above paragraphs have emphasized infrastructure issues, the concept of resilience applies equally to the socio-economic fabric. More than one disaster case study has shown how safe building or recovery has been delayed or paralyzed as a result of lack of enforcement of existing codes, lack of incorporation of natural hazards into planning activities, bureaucratic inefficiency, incompetence, corruption or other human factors (IFRC, 2001). Creating resilient communities requires a culture of disaster awareness, good policy and political will. Without these elements, success is unlikely.

Cultural change is difficult to achieve. At a minimum, it requires social learning and adaptive capacity. Through social learning (which emphasizes the importance of observing and modelling the behaviors, attitudes, and emotional reactions of others), people can learn from the experience of others who have reacted to disasters in constructive ways. Increasingly, it is thought that social cohesion is critical for societies to prosper economically and for development to be sustainable. A lack of institutions and networks can be a strong barrier to cultural change, even with the occurrence of social learning. Finally, there must be a capacity for adaptation, both in terms of infrastructure and within the socio-economic framework. Capacity depends upon many factors, including human, physical and economic resources and institutions capable of change. White et al. (2001) explored various reasons as to why disaster losses have been increasing, and conclude that, to a large extent, knowledge of how to reduce losses exists, but was not used effectively. This suggests that the solution to the disaster problem lies more in the social than in the physical or engineering sciences. In order to create a less vulnerable society, is seems that we must learn to do things differently.

Moreover, increased resilience means expanding the boundaries of what we value. Simply directing our attention to narrow, anthropocentric concerns means missing out on wider questions of *appropriate fit* between our own policies and environmental constraints. For too long, we have envisioned ourselves as *above* the environment, rather than as members of the biotic community (LEOPOLD, 1949). As a result, we have operated under the belief that nature could be molded to our own desires and dominated through technical quick-fixes. Some philosophers argue that healthier human settlements can only emerge through respectful attitudes towards the environment that assign it intrinsic worth, rather than mere instrumental value (LEOPOLD 1949; DEVALL and SESSIONS, 1985). For many, it is also a source of wonder and beauty and, in that sense, of value in its own right.

Whether or not one chooses to assign intrinsic value to the natural environment, most environmentalists do agree that, rather than centering purely on human concerns, a more appropriate ecological model of ethics means focusing on the *relation between* human beings and the natural world. It is when the *relationships* are out of balance – and included are those cases of heavy-handed technological manipulation of natural systems that ultimately compromise human and environmental health and safety – genuine disaster mitigation is at serious risk. Natural disasters are most fundamentally a social/political problem, rooted in the manner in which humans interact with their natural environment. Increasingly, the hazards literature emphasizes how development decisions made by society determine future disasters by placing us at risk (MILETI, 1999). The term "natural disaster" is somewhat of a misnomer, since the cause of disasters is often complex, and embedded in human decision making about one's proper place in the world.

Our worsening relationship with the natural world relates to natural disasters in two ways. Firstly, humans tend to deal with natural hazards by either ignoring them (for example, by building in floodplains) or by transferring risk to future generations by designing vulnerable systems or communities that will eventually suffer a disaster. The difficulties experienced in obtaining international consensus and approval of the United Nations Framework Convention on Climate Change, designed to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system is one good example of this at the global level. Secondly, our use of the environment for economic growth results in environmental degradation that often increases risk. Examples of this include climate change, devegetation of slopes resulting in more land and mudslides, and the paving of urban areas resulting in greater runoff and flooding.

Some of these ecological relationships are schematized in figure 1. In the center of the figure are two boxes with solid lines, which represent our human and natural environments. The human environment box is placed within the natural environment one, emphasizing the ecological perspective taken by this paper. Within the human environment box is a circle representing our interaction with those parts of nature that can potentially be resources for society, or hazards.

Component **A** represents that part of society vulnerable to nat-

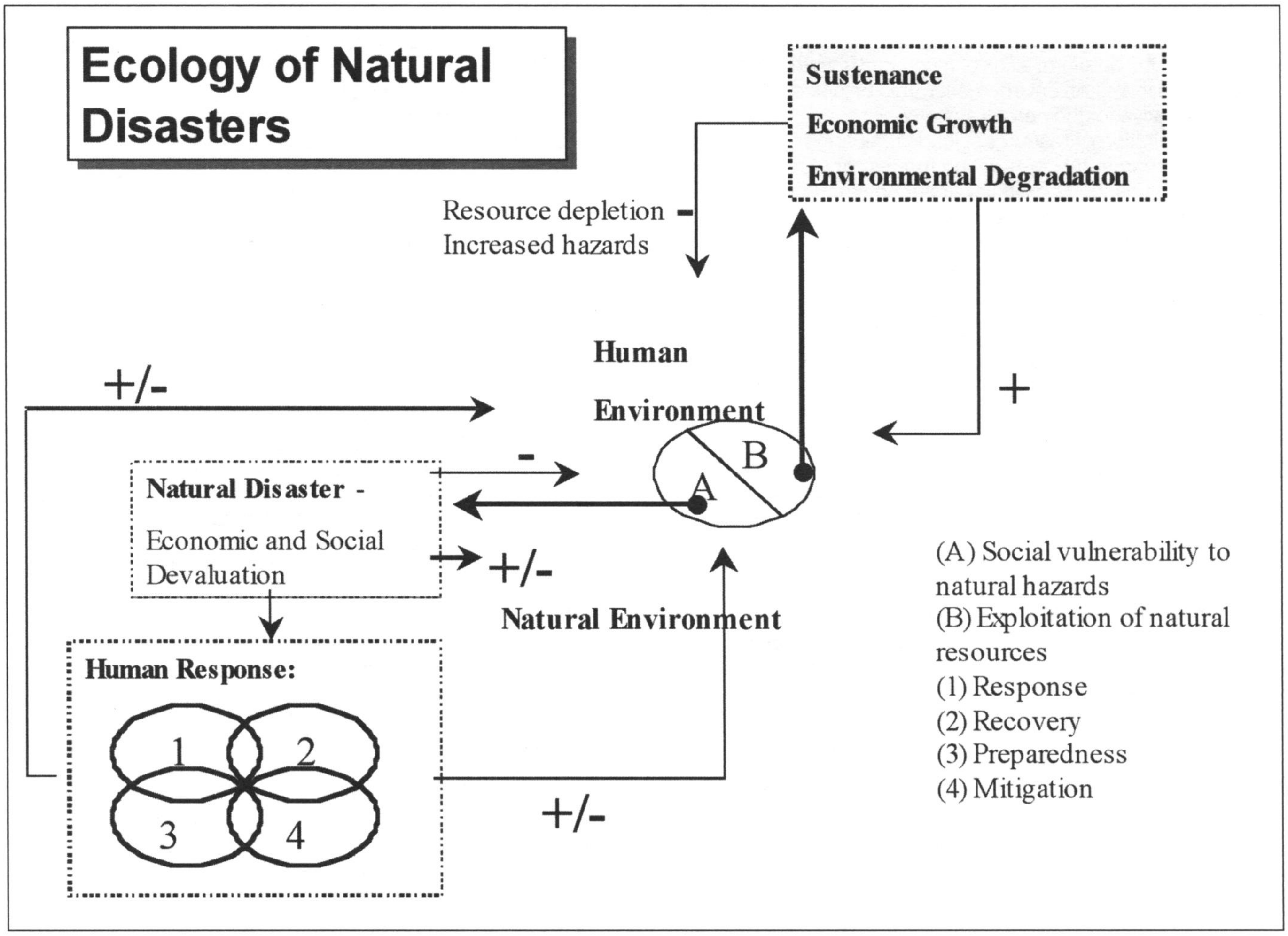

Fig. 1: This flow chart illustrates how the complex relationship between the human and natural environment contributes towards natural disasters. (*Source:* Adapted from Burton at al., 1993).
Note: The human environment is situated within, as opposed to separate from, the natural environment. Within the human environment, nature can be either a resource or a hazard. Where it is a resource (B) it leads to sustenance, economic growth, but also environmental degradation (the top right cycle). Therefore it can feedback in a positive way into the human environment, especially in the short term, but also in a negative way, where environmental degradation leads to increased hazards. Where the natural system is hazardous and social vulnerability exists, natural disasters can occur (the bottom left cycle). Such disasters have an immediate negative impact on society, but also trigger a complex cycle of human response that affects both the natural and human environments. These responses are intended to reduce vulnerability, but at times have increased it, and therefore the feedbacks are shown to be both positive and negative.

ural hazards, and those hazards. An example would be a city built near a fault line, and therefore subject to earthquake risk. This is essentially a simple representation of the "disaster pressure model" discussed in Blaikie et al. (1994), which defines risk as a function of both hazard and vulnerability.

Component **B** represents that part of nature which is a resource, and exploited by humans for sustenance and economic growth (such as harvesting forests for lumber, urban development, paving over land for urban development, or converting the natural landscape into agricultural land). The idea that nature is both a resource when it functions within our coping range, and a hazard when it exhibits extremes beyond that range has been explored, for example, by Burton et al. (1993, p. 32).

This flow chart illustrates how the complex relationship between the human and natural environment contributes towards natural disasters. The human environment is situated within, as opposed to separate from, the natural environment. Within the human environment, nature can be either a resource or a hazard. Where it is a resource (B) it leads to sustenance, economic growth, but also environmental degradation (the top right cycle). Therefore, it can feedback in a positive way into the human environment, especially in the short term, but also in a negative way, where environmental degradation leads to increased hazards. Where the natural system is hazardous and social vulnerability exists, natural disasters can occur (the bottom left cycle). Such disasters have an immediate negative impact on society, but also trigger a complex cycle of human response that affects both the natural and human environments. These responses are intended to reduce vulnerability, but at times have increased it, and therefore the feedbacks are shown to be both positive and negative.

From these boxes there are various arrows pointing in and out, with + and - signs beside them. Those signs are meant to represent the average direction of feedback, either positive (constructive to the system) or negative (destructive to the system). Clearly, there are value judgments inherent in these terms, and what one person may consider constructive, another may consider destructive. We suggest that the terms be interpreted within the context of total resources within the system and complexity; greater resources and increased complexity would be reflected by a +. Therefore, a flux of resources from the natural environment to the social environment would be positive for the social but negative for the natural system.

"B" (exploitation of resources) leads to economic growth but also to environmental degradation (on average), and is represented by the dashed box in the upper right hand corner of the figure. This results in feedbacks into the human and natural environments. One leading to the human environment is positive, reflecting how the use of natural resources enhances our society. However, the feedback into the natural environment is negative, as our experience is dominantly that environmental degradation has resulted from resource exploitation. This feedback has the net result of increasing risk by altering the hazards themselves.

"A," where extreme natural events act as a trigger to vulnerable systems, leads to natural disasters. Disasters typically trigger an overlapping and complex cycle of human behavior, starting with response and recovery, but often also including preparedness and mitigation. The latter two activities do occur in a continuous fashion in theory, but experience has shown that changes in behavior occur most often following disasters, within what is often called a "window of opportunity."

Environmental values and the nature of the relationship between humans and nature play a crucial role in the nature of the feedback loops involving "A" and "B". Where nature is not valued, or when the links between human and natural environments are discounted, then ultimately hazards are made worse or vulnerability is increased, though short-term benefits may accrue to social systems.

Some mitigation programs appear to have been ineffective, or even counter-productive in the long term. Examples of this include the Canadian federal disaster relief program in parts of Quebec (BENOIT et al., 2003) and some aspects of the U.S. flood insurance program (LARSON and PLASENCIA, 2001). The reasons for this are many and complicated – some are political, some are cultural, and some are technical. For this reason the feedbacks from the Human Response box at the bottom of figure 1, to the Social and Natural Environments box have a ± sign.

Mitigation activities, in order to be effective, need to reduce vulnerability. There are many different ways we can be vulnerable, including physical, personal, geographical, structural, environmental, cultural, social, economic and institutional.[5] These vulnerabilities are often linked in complex ways; for example, a poor economy can lead to a lack of institutional capacity and a greater use/misuse of environmental resources, with consequent environmental degradation. These linkages lead to the notion that any strategy designed to mitigate risk needs to be very broad-based. In particular, they should encourage a use of the natural environment that does not degrade it in ways that make hazards worse.

Recommendations for future action

If mitigation issues are complex, grounded in a holistic system of eco-ethical relationships, then clearly, interdisciplinary analysis is called for. Furthermore, to resolve conflicting ethical value judgments and taken for granted assumptions that underlie the development of any environmental policy, it makes sense to expand the discussion of ethics beyond human-centered parameters to include broader ecological values.

Such a discussion requires cultural change and the development of a cohesive interdisciplinary community. If such a change is to take place within Canada, we believe that a coherent community of hazards people needs to be formed. At present, hazards research and application is fragmented, with people mainly working within their own organizational, professional or departmental stovepipes. For this to change, institutions and/or networks need to be strengthened or created to encourage cross-disciplinary research: and to regularly bring practitioners, policy makers and researchers together from both the public and private sectors to share information and perspectives. In particular, city planners, people involved in emergency management and insurance, climatologists, geologists and hazard and disaster researchers in government and universities (particularly from the social sciences), as well as representatives from native communities, should begin to work together in interdisciplinary ways.

One useful model for such an institution is the Natural Hazards Center at the University of Colorado, Boulder, which houses a large library that is accessible by any person interested in hazards, publishes journals and newsletters, facilitates networking and holds an annual interdisciplinary workshop. Within Canada, the Canadian Risk and Hazards Network, the Institute for Catastrophic Loss Reduction, Publics Safety and Emergency Preparedness, Canada, the Geological Survey of Canada, the Meteorological Service of Canada and the Canadian Centre for Emergency Preparedness all take on some of these functions, and have the potential to assume a much larger role given the mandate and additional resources. The structure and characteristics of networks and institutions that enable cooperative behavior for the common good, in order to avoid "social traps" such as discussed by Hardin (1968) in "The Tragedy of the Commons," is an important topic, but beyond the scope of this paper. The reader is referred to Ostrom et al. (2002) for more discussion on this topic.

More effective mitigation means changing the way people think about hazards. This cannot be done solely by implementing new policies, standards or laws, though those tools are extremely important (consider how much of the damage caused by Hurricane Andrew in August 1992, in Florida occurred because existing standards and laws were not adhered to). It can be advanced by the interchange of ideas and experience by people who care and work with hazards issues.

Almost two decades ago, planner Spenser Havlick advocated increased exchange of documentation and experience, not only cross-regionally but internationally. "There is a need for new natural hazards research," he wrote, "which takes into account proper long term planning periods and for more international exchange of building codes and specifications which have proven effective in both disaster resistance and cost over a reasonable payback period" (HAVLICK, 1984, p. 404). Still today, researchers are calling for "a commitment to mutual understanding and collaboration among academics, professionals and laypersons, who are hazard specialists and academics, professionals and laypersons who are urban specialists" (MITCHELL, 1999, p. 46).

Certainly, electronic listservs, conferences, advisory groups and research centers are important elements of interdisciplinary collaboration. However, Havlick raised an important point when he suggested that "the greatest and most lasting contribution to the reduction of risk from natural hazards comes from the universities, the academies and other centers where architects, engineers and planners are trained" (1984, p. 405). His survey of universities at the time revealed almost no interdisciplinary courses on hazards mitigation and preparedness, and little has changed since then. Unless we are educating our students about how to make linkages, any long-term hopes for holistic understanding of the ecology of disaster mitigation is at serious risk.

It is difficult to underemphasize the importance of broad perspectives in solving real-world problems, and until our educational systems and professional development encourage such, it is unlikely that much progress will be made in the mitigation of natural disasters. It has been said that "a way of seeing is also a way of not seeing" (Kenneth Burke in KLEIN, 1990, p. 182). Our personal experiences, our personal and disciplinary biases and deeper underlying paradigms allow us to see mitigation from various, unilateral perspectives. It is only in a wider dialogue that collectively we can hope to evolve a broader, eco-ethical approach to disaster mitigation by moving our sights towards the greater whole.

Notes

1. It is a somewhat debatable point, whether these strategies are classified as 'modifying the hazard' or as 'modifying vulnerability.' For example, if you build a house on a flood plain, the house is vulnerable to flooding. If a dam is built so that the floodplain is changed, you have reduced vulnerability, but one could also argue that the hazard – the river – has been modified. For practical purposes the distinction is probably not important.
2. For a discussion of some of the contemporary interpretations of ecology, see Molles, Jr., 1999.
3. Frederick Clements, for instance, viewed ecosystems and the climax community as a complex organism – "a new kind of organic being with novel properties" (cf. Worster, 1985, 211). The community model itself was advanced by thinkers such as English zoologist, Charles Elton, who viewed ecosystems as functional models. By the early 20th century, English biologist Arthur Tansley moved toward an energy model of ecosystems, denying that they consisted of simply physical, mechanical elements but reflected complex energy flows. Our emphasis is on the theoretical importance of emphasizing fundamental, ecological relationships between human beings, living entities and biotic and abiotic environments.
4. Increased mitigation of risks from natural hazards has been addressed through Ontario's Emergency Readiness Act (Bill 148), which states that "Every municipality shall develop and implement an emergency management program," and through the Quebec Civil Protection Act (Bill 173), which requires municipalities to engage in risk identification, prevention and emergency response plans.
5. For a review on vulnerability, see, for example Anderson (2000), Hewitt (1997) or Blaikie et al. (1994).

References

ANDERSON, M.B. (2000), *"Vulnerability to disaster and sustainable development: A general framework for assessing vulnerability,"* in Pielke and Pielke (eds.), *Storms,* vol. 1 (New York, Routledge), pp. 10-25.

BASS, B. (2002), Personal Communication.

BENOIT, R., F. SIMON, and J. ROUSSELLE (2003), "The effectiveness of flood damage reduction measures in the Montreal region," *Natural Hazards* (in press).

BERKES, F. (1999), "Sacred ecology," *Traditional Knowledge and Resource Management* (Philadelphia and London, Taylor and Francis).

BLAIKIE, P., T. CANNON, I. DAVIS, and B. WISNER (1994), *At Risk – Natural Hazards, People's Vulnerability and Disaster* (London, Routledge).

BOOTH, Annie L. and Harvey M. JACOBS (1993), "Ties that bind: Native American beliefs as a foundation for environmental consciousness," in Susan J. Armstrong and Richard G. Botzler (eds.), *Environmental Ethics: Divergence and Convergence* (New York, McGraw-Hill), pp. 519-526.

BROWN, D.W., S.M.A. MOIN and M.L. NICOLSON (1997), "A comparison of flooding in Michigan and Ontario: 'Soft' data to support 'soft' water management approaches," *Canadian Water Resources Journal*, vol. 22, no. 2, pp. 125-139.

BRUNK, Conrad (1993), "Technological risk and the nuclear safety debate," in *Proceedings from a Workshop* (Ottawa, Ontario, Institute for Research on Environment and Economy), October 1-2.

BURBY, R.J. (2001), "Flood insurance and flood plain management: The US experience," *Environmental Hazards,* vol. 3, pp. 111-122.

BURTON, I., R. KATES and G. WHITE (1993), *Environment as Hazard* (2nd ed.), (New York, The Guilford Press).

CALLICOTT, J. Baird (1994), *Earth's Insights: A Survey of Ecological Ethics from the Mediterranean Basin to the Australian Outback* (Berkeley, CA, University of California Press).

China Online, 2003. http://www.chinaonline.com/refer/ministry_profiles/threegorgesdam.asp. Accessed July 7, 2003

CRICHTON, D. (2001), Personal Communication.

DEVALL, B. and George SESSIONS (1985), *Deep Ecology: Living as if Nature Mattered* (Salt Lake City, Peregrine Smith Books).

DORE, M.H.I. (2003), "Forecasting the conditional probabilities of natural disasters in Canada as a guide for disaster preparedness," in *Natural Hazards,* vol. 29, no. 2-3, pp. 249-269.

DOXIADIS, C.A. (1968), *Ekistics: An Introduction to the Science of Human Settlements* (New York, Oxford University Press).

ENVIRONMENT CANADA (2002), *Science and Environment Bulletin*, Issue No. 32 (September/October). Also available on the website: www.ec.gc.ca/science.

—— (2003), http://www.mb.ec.gc.ca/nature/whp/ramsar/df02s06.en.html. Accessed July 7, 2003.

ETKIN, D.A. (1999), "Risk transference and related trends: Driving forces towards more mega-disasters," *Environmental Hazards,* vol. 1, pp. 69-75.

GELMAN, Ovsei and Santiago MACIAS (1984), "Toward a conceptual framework for interdisciplinary disaster research," in *Ekistics*, vol. 51, no. 309 (November/December), pp. 507-510.

GUNDERSON, L.H. and C.S. HOLLING (eds.) (2002), *Panarchy: Understanding Transformations in Human and Natural Systems* (Washington, DC, Island Press), 507 pp.

HARDIN, Garre (1968), "Tragedy of the commons," *Science*, vol. 162, pp. 1243-1248.

HAVLICK, Spenser W. (1984), "The urgency of accelerated application of natural hazards research findings in human settlements," *Ekistics*, vol. 51, no. 308 (September/October), pp. 398-405.

HAUDENOSAUNEE ENVIRONMENTAL TASK FORCE (1992), *Words that Come Before All Else: Environmental Philosophies of the Haudenosaunee* (Task Force).

HEWITT, K. (1997), *Regions of Risk – A Geographical Introduction to Disasters* (Longman), p. 389.

HOFFMAN, S. (1998), "Eve and Adam among the embers: Gendered patterns after the Oakland Berkeley firestorm," in E. Enarson and B.H. Morrow, *The Gendered Terrain of Disaster: Through Women's Eyes* (Florida International University), pp. 55-62.

HOLLING, C.S and L.H. GUNDERSON (2002), "Resilence and adaptive cycles" in L.H. Gunderson and C.S. Holling (eds.), *op. cit.,* pp. 25-62.

INTERNATIONAL FEDERATION OF RED CROSS AND RED CRESCENT SOCIETIES (2001), *World Disasters Report: Focus on Recovery* (Bloomfield, CT, Kumarian Press).

INTERNATIONAL MONETARY FUND (IMF) (2003), *"The IMF's poverty reduction and growth facility,"* http://www.imf.org/external/np/exr/facts/prgf.htm. Accessed July 10, 2003.

KLEIN, Julie Thompson (1990), *Interdisciplinarity: History, Theory and Practice* (Detroit, Wayne State University Press).

LARSON, L. and D. PLASENCIA (2001), "No adverse impact: New direction in floodplain management policy," *Natural Hazards Review,* vol. 2, no. 4 (November), pp. 157-181.

LEMAN, Alexander B. (1980), "Human settlements: Framework for disaster assessment," in *Housing Science*, vol. 4, no. 6.

LEOPOLD, A. (1949), *A Sand County Almanac with Other Essays on Conservation from Round River* (New York, Oxford University Press, 1949; reprinted in 1981).

MILETI, D. (1999), *Disasters by Design – A Reassessment of Natural Hazards in the United States* (Washington, DC, Joseph Henry Press).

MITCHELL, James K. (1999), "Natural disasters in the context of mega-cities," in James K. Mitchell (ed.), *Crucibles of Hazard: Mega-Cities and Disasters in Transition* (New York, United Nations University).

MOLLES, Manuel C., Jr. (1999), *Ecology: Concepts and Applications* (New York, McGraw-Hill).

NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ADMINISTRATION (NOAA) (2003), Atlantic Oceanographic and Meteorological Laboratory, Web Site, http://www.aoml.noaa.gov/hrd/hrd_sub/modification.html. Accessed Jan. 23, 2003.

O'BRIEN, Mary (2000), *Making Better Environmental Decisions: An Alternative to Risk Assessment* (Cambridge, MA, MIT Press, in association with the Environmental Research Foundation).

OSTROM, E., T. DIETZ, N. DOLSAK, P.C. STERN, S. STONICH and E.U. WEVER (eds.) (2002), "The Drama of the Commons," *Committee on the Human Dimensions of Global Change* (Washington, DC, National Academy Press), p. 521.

STEFANOVIC, Ingrid Leman (2000), *Safeguarding Our Common Future:*

Rethinking Sustainable Development (Albany, NY, State University of New York Press).
—— (2003), "The contribution of philosophy to hazards assessment and decision making," *Natural Hazards,* vol. 28, no. 2-3, pp. 229-247.
WHITE, G. (1999), "A conversation with Gilbert F. White," *Environmental Hazards,* vol. 1, pp. 53-56.
——, R.W. KATES and I. BURTON (2001), "Knowing better and losing even more: The use of knowledge in hazards management," in *Environmental Hazards*, vol. 3, pp. 81-92.
WORLD BANK (2002), *"Leadership capacity building for post conflict reconstruction."* http://www.worldbank.org/wbi/B_SPAN/sub_leadership_postconflict.htm. Accessed July 10, 2003.
WORLD METEOROLOGICAL ORGANIZATION (WMO) (1995), "Meeting of Experts to Review the Present Status of Hail Suppression," *World Meteorological Organization,* WMP Report No. 26, Golden Gate Highlands National Park, South Africa, WMO/TD No. 764.
WORSTER, Donald (1985), *Nature's Economy* (Cambridge, Cambridge University Press).
WYNNE, B. (1992), "Uncertainty and environmental learning: Reconceiving science and policy in the preventive paradigm," *Global Environmental Change,* vol. 2, no. 2, pp. 111-127.