Chapter 10

Ecosystem Health and Human Health: Healthy Planet, Healthy Living*

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Abstract

The links between human health and ecosystem health are clear for many people but inaction to bring a balance between the two is still omnipresent among decisionmakers and certain parts of our societies. There is a need for concerted efforts to first educate and inform all people in the world about these links and the fragility of the ecosystems in which we live. While some ecosystems might be able to restore their health without human interventions, it is clear that others may need our help. There are several potential solutions, the challenge being to engage the world in the implementation of these actions. This chapter explores some of these solutions and potential actions. These priority actions were in many cases proposed by the discussion group at the EcoSummit. There was a strong recognition of these priorities. The discussion group passed a resolution on conserving, protecting, and enhancing ecosystem health and human health. The main goal of our society should be towards a healthy planet and healthy living.

* We would like to dedicate this chapter to Andrew Hamilton, our working group rapporteur, who has worked on linking human health and the environment for many years. Thank you for your eloquent summary of our discussions, found in the resolution at the end of this chapter. It brought all our thoughts together in a common vision.

Understanding and Solving Environmental Problems in the 21st Century
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1. Introduction

Humans are altering the earth's environment in dramatic and increasingly pervasive ways. Through a variety of enterprises (e.g., industry, agriculture, recreation, and international commerce), humans are transforming fundamental natural processes such as climate, biogeochemical cycling, and even the biological diversity upon which evolutionary changes depend (Vitousek et al., 1997). Accompanying mounting evidence of human domination of the earth's ecosystems is growing recognition that ecosystem health is a critical prerequisite of human health and well-being (Cortese, 1993). Clearly, without key ecosystem services such as providing clean air, clean water, food, and a hospitable climate, life (human and other) cannot exist. In addition, the role that other ecological functions (e.g., disturbance regulation, biological control, and organic matter decomposition) play in supporting long-term biological health and stability has gained broader recognition (Costanza et al., 1997). The better understanding of human linkages to natural and altered ecosystems has been fostered, in part, through a growing number of research and case studies from around the world. Collectively, efforts like these have helped to define the risks posed by a myriad of long-recognized (e.g., asbestos, heavy metal, organic solvent exposures, etc.) and emerging (e.g., endocrine disruption, antibiotic resistance, interactive toxicity, etc.) ecosystem and human health issues.

Scientific evidence has helped illustrate some of the human and ecological costs of environmental degradation. However, it is unlikely that contemporary awareness fully incorporates all future threats posed to ecosystem and human health. In fact, current environmental issues may well be just a prelude of the consequences yet to come. The ever-increasing human population, along with an explosive increase in consumption, exacerbate and enlarge the footprint pressing on aquatic and terrestrial ecosystems as a result of land use from agriculture and human settlement, natural-resource use, activities such as transportation and recreation, and wastes from domestic, municipal, and industrial development. Even disregarding the possibility that interactions or synergies among the drivers and effects of anthropogenic ecosystem disruption could hasten system degradation, it seems clear that further erosion of ecosystem and human health is likely barring meaningful human response. Less certain, however, is how possible concurrent reductions in biological stress response systems might alter current trends. For example, evidence is accumulating that the widespread dispersal of synthetic chemicals may be altering animal hormone and immune systems that are needed for normal growth, development and disease resistance (Soto et al., 1996; Nilsson, 2000). Other work suggests that anthropogenic disturbance of ecosystem nutrient relations may diminish the capacity of plants to sense, respond to, and/or survive an array of environmental stresses (DeHayes et al., 1999). In addition, reductions in biodiversity could eliminate keystone species,

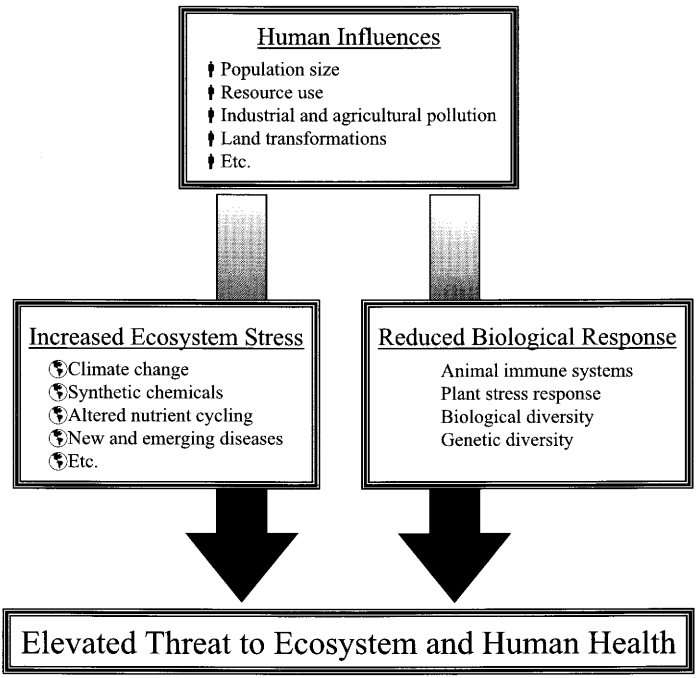

Fig. 1. Conceptual model of the dual threat (increased stress and reduced response/resistance that human population growth and activity pose to ecosystem and human health.

create discontinuities in ecosystem nutrient and energy pathways, and enhance vulnerabilities to significant losses of ecosystem services following natural or man-made disturbance (Tilman, 2000). Losses of genetic diversity within species would also reduce the capacity of populations to successfully adapt to environmental change (DeHayes et al., 2000). Especially if environmental perturbations are pronounced (e.g., as predicted under some climate-change scenarios), disruptions in the ability of biological systems to accommodate change might have dramatic ecological, health, economic, and social impacts.

In essence, human activity may be subjecting individuals and ecosystems to unprecedented levels of environmental stress by diminishing biological mechanisms to successfully respond to them (fig. 1). In addition, social conflicts (e.g., growing inequities in income distribution and consumerism) can unfold to exacerbate detrimental impacts to vulnerable populations. These combined factors are likely to threaten the function, health, and sustainability of ecosystems worldwide with a speed and intensity never before realized. Our knowledge of the causes and consequences of unprecedented human intervention in the natural

world is growing. Yet, much may remain unknown until the current "experiment" with global health progresses further.

The threat to ecosystem health and human health posed by anthropogenic activities is real. Contemporary examples of damage are well documented, and current predictions of future impacts are supported by sound science. However, predictions of escalating harm are likely valid only in the face of inadequate human response. But what are the *appropriate* responses to the complex environmental problems we face?

This chapter summarizes the discussion and analysis of contemporary ecosystem health problems that occurred during the EcoSummit 2000 in the Working Group on Ecosystem Health and Human Health. The working group consisted of a heterogeneous amalgamation of participants from over 12 countries and a wide range of disciplines (including scientists from social, economic, biological, engineering, environmental, and medical specialties, as well as clergy, policymakers, and students representing a wide range of disciplines), who collectively brought a diverse mix of perspectives to the discussions. The aim of this EcoSummit was to encourage integration of both the natural and social sciences with the policy- and decisionmaking community for the purpose of developing a deeper understanding of complex environmental problems. A foundational premise was that this enhanced understanding is a necessary prerequisite for the debate and action needed to build a sustainable future that protects ecosystem and human health.

This chapter's structure mirrors the progression of discussion for the working group. To initiate the cycle of discussion, and help focus interactions, five broad questions were sequentially examined. These questions were:

(1) What are the linkages between human health/disease and ecosystem health?
(2) What are technological, social, political, and economic sources of solutions to the problems?
(3) What are the priority actions that should be taken to protect, preserve, or restore the health of ecosystems and growing human populations?
(4) What are the barriers to effective action?
(5) What are useful measures, indicators, or metrics of progress?

While the first question overlaps the general overview presented in the previous chapter on ecosystem and human health, several arguments are included here to reinforce the conceptual and functional linkages between ecosystem and human health. Because the questions discussed involved material of a highly intricate nature and vast scope, additional focus was provided by primarily examining these questions within the context of three global issues that all participants could relate to: climate change, agrosystems and food production, and biodiversity. As a capstone to discussions, a statement was written to summarize the positions and priorities that emerged, and to provide a unified call to improve communication

and actions that foster ecosystem health and human health. This statement, written in the form of a resolution, closes the chapter[1].

2. Linkages between ecosystem health and human health

Underpinning group discussion was the shared view that human health and ecosystem health are inexorably linked and interdependent. "The atmosphere, fertile soils, freshwater resources, the oceans, and the ecosystems they support, play a key role in providing humans with shelter, food, safe water, and the capacity to recycle most wastes" (World Health Organization, 1997). This section underscores some of the linkages between key natural resources (i.e., air, water, food, soil, and biological diversity) and ecosystem/human health targeted during group discussions. Although examples of the health costs of ecosystem degradation are many and can be found throughout the world, this section highlights examples from Canada (the host country for EcoSummit 2000) and other regions most familiar to discussion participants. In addition, to adequately address the complexity and diversity of the environmental problems the world faces, the group proposed that new paradigms for understanding the linkages between ecosystem and human health were needed. Accordingly, this section on linkages closes with a call from the group for an expanded perspective when considering models for integrating environmental and biological health.

2.1. Air quality

Air quality can be examined at the local or global level, as airborne pollutants can travel long distances linking ecosystems from various regions of the world. Unfortunately, there are ecosystems that are more vulnerable to air pollutants than others because (due the vagaries of air currents and/or topography) they act as sinks for the residues of atmospheric contamination. As a result, these ecosystems can suffer elevated health burdens. For example, the Arctic ecosystem is highly vulnerable to long-range transport pollutants, which have contaminated all nodes of the food web. First Nations and Inuit peoples are two groups whose homelands have been disproportionately affected by this ecosystem contamination (Commoner et al., 2000). Generally in Canada, however, air quality has been improving. And, although average annual levels of ground-based ozone increased 29% between 1979 and 1993 (Health Canada, 1997), the number of days for which ground-level ozone posed a high health risk generally declined in Canada over the last 25 years (although there is a large fluctuation from year to year due to

[1] A note to the reader: although citations occasionally appear in this chapter, they are included simply as a supplement to the review of group discussion presented herein.

weather-related and other sources of variation). Despite this improvement, high ozone levels still occur frequently in certain parts of Canada when episodes of hot, stagnant weather coincide with periods when local and transported emissions of precursor contaminants are high (Environment Canada, 1999).

Air pollution poses an overwhelming global threat to ecosystem and human health. Worldwide, an estimated 3 million deaths are attributed to air pollution (World Health Organization, 1997). In Canada, the number is approximated at 5000 annually (Environment Canada, 2001). Through a myriad of ways (including reduced lung capacity, eye, nose, and throat irritation, aggravation of lung and heart disease, etc.) most Canadians can expect to be personally impacted by poor air quality at some time in their life (Health Canada, 1997).

Although poorly quantified, air pollution has also altered the health of sensitive forest ecosystems (e.g., see Mickler et al., 2000), perhaps forewarning a broader disruption in ecosystem structure and function as the native resiliency and buffering capacity of systems are depleted. The impacts of air pollution can be direct (e.g., ozone injury to leaf physiology and tree health), or can involve chemical transformations in the environment that can lead to broader ecosystem disruption. For example, pollutants such as sulfur dioxides and nitrogen oxides can react with atmospheric moisture to create sulfuric and nitric acids, which precipitate to the earth as acid deposition. These acidic inputs can lower the pH levels of lakes and other surface waters, increase the solubility of metals such as aluminum and mercury that usually have low biochemical availability, reduce the number of plant and animal species that aqueous ecosystems can support, and can thereby disrupt the energy and nutrient relations of surrounding environments. Similarly, pollutant-induced depletion of the protective ozone layer is now allowing more UV radiation to reach the earth's surface. Because DNA absorption of UV increases the rate of genetic mutation, ozone depletion increases the risks of skin cancer among humans and may be one factor raising mutation rates in vulnerable wildlife species such as frogs (Wardle et al., 1997). In these and many other ways, human disruption of one resource can "spill over" and influence other critical life-support systems.

2.2. Water resources

Canada contains 9% of the Earth's fresh water supply (Environment Canada, 2000). Although most Canadians have access to one of the safest drinking water supplies in the world, water reserves here are not uniformly free of contamination. For example, as noted for air quality, First Nations and Inuit communities have a disproportionate exposure to contaminated water supplies. In fact, the incidence of waterborne diseases is several times higher for Aboriginal communities than for the broader Canadian public (Federal, Provincial and Territorial Advisory Committee on Population Health, 1999). However, the greater tendency for rural

native peoples to experience tainted water supplies does not indicate that water systems in the rest of Canada are free from problems. For example, an *E. coli* outbreak in the water supply of Walkerton, Ontario, Canada – a small rural town – left 7 dead and over 2000 ill. This tragedy prompted an increased analysis of ground water throughout Canada, and showed that, for a variety of reasons, microbial and chemical ground water contamination in the entire country was far worse than previously assumed. On a global scale, it is now predicted that limitations of fresh potable water will be a focal point of human health concerns and a significant contributor to regional conflicts as disputes over water resources escalate (Postel, 1999). According to the WHO, "over 1000 million people do not have access to an adequate supply of safe water for household consumption" (World Health Organization, 1997). Although already extremely high, the number of people living with inadequate clean water supplies will likely rise dramatically in the near future as human population growth and increased water use outstrip supply capacities. Water deficits are predicted to be particularly large in certain locations including India, China, parts of the USA, and Africa (Postel, 1999). Water shortages increase the diversion of dwindling natural reserves to supply human demands, with urban/manufacturing applications typically favored over agricultural uses. Whatever the use, a greater human sequestration of water results in a reduction of supplies left to support ecosystem function and health.

Dams, levees, and other forms of hydraulic infrastructure exist because they serve real human needs (e.g., increased water supplies for drinking, irrigation and industry, flood control, and hydroelectric power). However, these same waterways have historically served important ecological functions such as the buffering of floodwaters, assisting with nutrient cycling and dispersion while maintaining salt and sediment balances, protecting wetlands and their ability to absorb pollutants, and providing critical habitat for a diverse array of aquatic species (Postel, 1999). Unfortunately, as currently designed and operated, engineered water control systems almost exclusively fulfill human needs and rarely accommodate other ecosystem services. This apparent schism between meeting both human and ecosystem needs has increased relevance in light of the substantial and growing control of humans over freshwater resources (Postel, 1999). For example, it has been estimated that about 77% of the river systems in the USA, Canada, Europe, and the former Soviet Union are moderately to strongly altered by dams, reservoirs, diversions, and irrigation (Dynesius and Nilsson, 1994). In fact, human diversion and exploitation of water resources is so great that little or no fresh water reaches the sea during parts of the year for numerous river systems worldwide including the Yellow (China), the Colorado (North America), the Ganges and Indus (South Asia), the Amu Darya and Syr Darya (Central Asia), and the Nile (northeast Africa) rivers (Postel, 1999). Among its many impacts, overexploitation of freshwater resources has severely threatened dependent plant

and animal species, and helps to account for the elevated risk of extinction for fish species worldwide relative to other life forms (Postel, 1999).

2.3. *Food resources*

Worldwide, food is one of the major routes of exposure for many pathogens and toxic chemicals (World Health Organization, 1997). The increased interdependency and complexity of the world's food supplies has helped to strain production and distribution systems, and contributed to recent increases in food-borne disease (World Health Organization, 1997). In Canada, the food supply is generally safe. However, as a result of food-borne bacterial contamination, an estimated 10 000 cases of food-related illness are reported every year (Health Canada, 1997). Other forms of contamination, although currently rare, are also of increasing concern. Food also accounts for 80–95% of our total daily intake of persistent organic pollutants, including PCBs, dioxins, furans, and PAHs (Health Canada, 1997). As with air and water resources, First Nations and Inuit people suffer disproportionately from food-borne pollutant exposures. In particular, their traditional diet of fish and marine mammals places them more at risk of exposure to environmental contaminants such as PCBs and mercury (Health Canada, 1997). For instance, PCB concentrations in breast milk of Inuit women in Northeastern Quebec are five-fold higher than levels of PCBs in breast milk of women in Southern Quebec (Health Canada, 1997; Commoner et al., 2000). The most probable source of airborne contaminants such as PCBs and dioxins is long-range atmospheric transport, with Arctic ecosystems being major sinks where pollutants bioaccumulate in food chains affecting entire ecosystems from algae to humans (Commoner et al., 2000). However, fish and game contamination is not only of concern to people living in polar ecosystems, but is relevant in many regions where diets include game species (e.g., Langlois et al., 1995; Tsiji et al., 1999), and has been documented for some commercial foods as well. For example, the US Food and Drug Administration recently advised that shark, swordfish, king mackerel, and tilefish (all long-lived, large fish that feed on smaller fish) can accumulate high levels of methyl mercury. Consequently they recommended that vulnerable segments of the population (i.e., pregnant women, women of childbearing age, nursing mothers and young children) not eat these commercially available fish species (US Food and Drug Administration, 2001).

Identified contamination results in consumer advisories that hopefully limit direct health risks to human consumers. But what about contamination that is not officially documented? Are humans cautioned against these possible risks? And what risks do heavy-metal and synthetic-chemical accumulations pose to ecosystem health and function? The potential ecological damage of chemical bioaccumulation in aquatic food chains is well documented, and research is now assessing the risk to terrestrial systems (e.g., Lasorsa and Allen-Gil, 1995). Still, information on the impacts of certain forms of contamination on

ecosystem function and health has long been reported. Indeed, Rachael Carson's groundbreaking book *Silent Spring* helped instigate the modern environmental movement by exposing the untold threat that pesticides like DDT pose to ecosystem food chains and the health of associated wildlife populations. More recent works have expanded the scope of concern about widespread pesticide contamination to include a number of emerging issues including the possible destruction of beneficial natural predators and parasites, and the ecological consequences of pesticide resistance in pests (Pimentel et al., 1992). Even with recent gains in understanding, the long-term, cumulative, interactive, and potentially synergistic impacts of pesticides and other forms of chemical/heavy metal contamination on ecosystem health remain far from resolved.

2.4. Soils

Soil plays a critical role in the Earth's life support system. Canada has approximately 5% of its total land area that is suitable for agricultural purposes, and only one-half of this is considered prime agricultural land (Acton and Gregorich, 1995). There are many factors reducing the quality of the soil in Canada, including erosion, loss of organic matter, compaction, as well as urban sprawl, the increased use of agricultural chemicals, and unsound waste management practices (Acton and Gregorich, 1995). An extreme example of land degradation is desertification. While droughts and fires can be considered natural causes for desertification, increasing human density, livestock ranching, fuelwood harvests, and deforestation are more important drivers of desertification than was previously recognized (Barrow, 1991). Grassland ecosystems in all regions of the world are subject to overexploitation and unfavorable weather patterns, which can also promote desertification. Desertification induces an obvious and dramatic alteration to ecosystem structure, function, and health, which translates into dire problems (e.g., possible malnutrition, starvation, refugee and migration issues, associated increases in communicable disease, and death) for dependent human societies.

2.5. Biodiversity

Human activity is driving the extinction of plant, animal, and microbial life at a rate thousands of times above estimated natural levels (Chivian, 1993). Indeed, human alteration of the global environment has likely triggered the sixth major extinction event in the history of life on earth (Chapin et al., 2000). Currently, in the USA, the major threats to biodiversity are thought to be habitat destruction and degradation, alien species, pollution, over-exploitation, and disease (in descending order of importance) (Wilcove et al., 1998). Locally and even regionally, the relative influence of these drivers of species loss often varies. In Canada, for instance, the impact of alien species may be somewhat elevated: it is estimated that about 25% of plant life in Canada is now of non-native origin (Vitousek et al., 1997). Examples such as the proliferation of zebra mussels and lamprey eels in

Box 1
Sources of solutions

It was the intent of organizers that the discussions and subsequent actions of participants in the working group on Ecosystem Health and Human Health would help contribute sources of solutions to ecosystem and human health problems. By encouraging the integration of the natural, social, and health sciences with policy- and decisionmaking communities, it was hoped that a deeper understanding of complex environmental problems could be developed. Furthermore, there was an expectation that the debate and discussion conducted could stimulate participants into taking meaningful action following the conference. There was also some promise that the professional contacts made at the EcoSummit would lead to productive collaborations that could help address ecosystem health issues in new and innovative ways.

Indeed, although the discussions of the working group were centered on the five questions that are the focus of this chapter, there was a constant undercurrent of desire that the group's efforts lead to something more constructive than just more talk. Clearly, discussions reinforced participant beliefs that ecosystem and human health are co-dependent and jointly in peril. However, this belief grew so strong that members also felt compelled to act. The publication of this chapter was one action intended to help build a better understanding of, and catalyze solutions for ecosystem health problems. In addition, members developed a list of broad goals and specific objectives to guide their own efforts to improve ecosystem and human health following the conference. These goals focused on

(1) improving the knowledge about the linkages of human and ecosystem health,
(2) supporting the dissemination of this knowledge through education and better communication, and
(3) using this knowledge to direct and promote meaningful change.

To be most effective, it was proposed that these activities be applied across a spectrum of scales, ranging from personal, to groups of targeted individuals, to society at large. The specific objectives outlined explicit actions (e.g., the development of local conferences or courses on ecosystem health, trying to convince one opinion leader of the importance of ecosystem health to human health, making personal changes in lifestyle to reduce consumption of non-renewable resources and energy, etc.) that participants could engage in to further prioritized goals. Some of these actions are now being realized. Several participants from the Faculty of Medicine & Dentistry at The University of Western Ontario (London, Canada) were so compelled by the discussions at the EcoSummit, that they organized a Primer Course in Ecosystem Health that was hosted by their University in June 2001 (see www.med.uwo.ca/ecosystemhealth). This course provided a strong background in the fundamentals of ecosystem health to a range of professionals and students who might not otherwise connect the need for ecosystem integrity with the sustenance of human health.

Only time will tell if participants will actualize the goals and fulfill specific objectives outlined during EcoSummit 2000. However, if the enthusiasm generated by group discussions is any indication, it is reasonable to expect that members will work to instigate meaningful personal and societal change and improve the health of world ecosystems and human populations.

working group proposed a series of considerations that members felt should be at the center of the continuing debate. Participants concluded that ongoing efforts to solve ecological/human health problems should focus on,

(1) Maximizing *global* human well-being;
(2) Ensuring *long-term* ecological sustainability/integrity;
(3) Preserving *all* aspects of biodiversity; and
(4) Creating the necessary *linkages/connections* for sustainable development.

Due to the geographic diversity represented by group members, issues of place and culture were always at the forefront of discussions especially when discussing solutions to environmental problems. Members recognized that solutions should be tailored to the communities in which problems occur. Throughout discussions, whenever solutions to environmental problems were addressed, a primary consideration raised was whether or not they were appropriate to local biological and social systems. One after another, group members recounted examples of well-intended "solutions" to environmental problems that failed because they did not accommodate local needs. As a result, a consistent theme emerged: flexibility in approach was often a cornerstone to successful environmental problem solving. Whether defining the appropriate level of technology needed, pertinent social constraints or enhancement opportunities, or even deciding the appropriate scale needed (e.g., neighborhood? district? region?) to capture "local" variation, it was agreed that planning should be flexible and solutions adapted to the situation at hand. It was emphasized that, although stringent goals concerning environmental quality are needed to prevent the continued degradation of ecosystem services, these goals might be achieved more rapidly, efficiently, and effectively if flexible approaches to implementation are employed.

Another offshoot of the considerable diversity embodied within the working group was that issues of equity were often raised. Admittedly, the human enterprises that help drive environmental degradation often impart some benefit (often economic) to certain groups or individuals. Clearly, neither the benefits of healthy ecosystems nor the harmful externalities of environmental damage impact all people or nations equally. The distribution of environmental "goods" and "bads" is unequal, and this inequity is itself a powerful driver perpetuating environmental harm and ecosystem decline. In effect, if individuals, businesses, or governments *perceive* that the net impact (goods – bads = net) of their actions is favorable to them, the incentive to change is often limited. However, assessments of net impact are traditionally incomplete and often undercount the full costs of resulting ecosystem dysfunction. Considering this, it was suggested that one promising source of solutions to environmental problems could be an effort to educate individuals about their connection to associated degradations of ecosystem and human health. Enhanced awareness of personal impacts may prompt individuals to adjust their "internal accounting systems" (and the perceptions/actions they support) to better reflect the true costs of existence. But what kind of educational experience has enough personal relevance to actually alter ingrained perceptions of how the world works? For some people, the source of this inner growth is "experiential leaning" (hands-on learning that results from personal experience).

Several members of the working group had considerable experience with programs that personally involved individuals with the day-to-day battle to improve local environments. A good example of this was the urban farming

project established by Reverend Joseph Ebenezer in Chicago, Illinois, USA. Reverend Ebenezer described to the group his ambitious program that used abandoned lots, backyards, and rooftops as locations for community agriculture and aquaculture projects. These projects reap multiple benefits to the communities they serve (mostly poor or marginal communities): they provide nutritious food, they invigorate a sense of self-reliance and empowerment, and they help build a positive community identity. Importantly, the organic gardening techniques employed also teach valuable lessons in biology and ecology that transform the fundamental perceptions of food and health for these urban participants who otherwise might have little connection to the land.

Another prominent example of experiential learning discussed was the trend for colleges to require students to perform community service as a requirement for graduation (e.g. Canada, the USA and South Africa). The goal of these programs goes beyond a desire for students to contribute to community welfare. Implicit as well is the realization that service to others can be a life (and perception) altering experience. What better way is there to learn about new and sometimes very different realities than to live them? Indeed, perhaps if more of us experienced the net environmental impacts that others are forced to live with, our perceptions and associated actions would evolve to reduce pervasive environmental destruction.

4. Priority actions

It was emphasized repeatedly throughout group discussions that the seeds of change originate at the individual level. Indeed, group dialog focused on the fundamental importance of personal change as a prerequisite for broader societal reform. At some point, however, individual beliefs and action must translate into accomplishments at the institutional and societal levels in order to be fully effective. Governmental and corporate policies and management can have a pronounced and widespread influence on ecosystem health and human health. Clearly they cannot be ignored. In fact, the road to a healthier future will likely be built on an assortment of very specific changes in public policy and management. In addition, once an array of management options has been identified, a global consensus will be needed. Past agreements like those made in Stockholm, Rio, and Kyoto have proved to be insufficient. Restoring ecosystem and human health will require that thorough measures be prescribed and enacted globally. Although at one time many considered zero population growth to be "the answer" to ecosystem health problems, it is now broadly recognized that comprehensive reforms including reductions in resource consumption (particularly in developed nations that disproportionately deplete world reserves) must accompany population control.

As outlined earlier, the detrimental environmental and health consequences of growing populations and escalating human activity are many. Even fundamental

Box 2
Prioritizing issues: group analysis versus systematic review

As one means of focusing group discussion and guiding subsequent individual or collective action, participants compiled a list of serious threats to ecosystem and human health. Over the course of the conference, participants individually prioritized these issues from most to least "important", and toward the end of deliberations a synthesis of individual rankings was produced to create a composite tally of the relative importance of identified issues. The resulting composite listed 17 issues that ranged from #1 – climate variability and associated natural disasters, to #17 – the potential ecological threat of genetically modified organisms. The group recognized that there were many imperfections in this somewhat hastily prepared collective prioritization. Clearly it was redundant. For example, 6 of the 17 issues had interconnected ties to climate change (e.g., climate variability, rising atmospheric CO_2, rising global mean temperatures, etc.). In addition, in retrospect there were many important existing or emerging threats to ecosystem and human health (e.g., heavy-metal pollution, the growing resistance of microorganisms to antibiotics, potential declines in human immune and ecosystem stress response systems, etc.) that were missing from this list. It also seemed that there might have been some confusion on what criteria to use for judging importance. Was importance based on the current threat to ecosystem and human health, or was it based on the potential threat at some time in the future? Was the importance level based on the scope of the problem (e.g., worldwide vs. local or regional), or perhaps it was influenced by the sensitivity of the issue to timely remediation (e.g., because a policy decision now could make a real difference in alleviating or preventing a problem later)?

Despite the missteps inherent in this informal attempt to rank problems, the group openly recognized that some prioritization of ecosystem health issues is needed to guide research directions and policy actions. There are limited funds available for ecosystem/human health issues, and policymakers justifiably want advice on how to get the most "bang for the buck" toward resolving those problems that are most threatening. Comprehensive cost–benefit analyses should be conducted that account for all the costs (including alterations in health, finances, societal, community, and personal impacts, etc.) and benefits (including broad definitions of ecosystem and human health) of existing actions and proposed changes. Such analyses would likely integrate a range of pertinent criteria (e.g., considerations of problem scope, timely remediation, etc.) that would influence assessments of relative risk. A recent book may provide an example of the kind of integrated analysis that needs to be done. For their book *The Consumer's Guide to Effective Environmental Choices*, Michael Brower and Warren Leon (1999) from the Union of Concerned Scientists synthesized a wide array of scientific information on the environmental impacts of various consumer practices to produce a virtual "top 10 list" of activities that most harm the environment. Importantly, they outline specific ways for consumers to lessen their contributions to these pressing threats against ecosystem integrity and human health. The resulting analysis and advice establish a documented and well-reasoned set of priorities that serve as a practical guide for consumers that could also be used by policymakers to help evaluate policy alternatives. Of course, even this relatively comprehensive assessment has many significant limitations to its use and relevance. For example, because it specifically focuses on the effects of consumer actions, it avoids a vast area of pertinent influence on ecosystem health: the impact of the government sector. In addition, like any report, it is an informational "time capsule", in this case reflecting a rational cost–benefit analysis at the time of publication (1999), but with an unknown duration of validity. Despite limitations like these, careful prioritizations of the relative risks of the numerous threats to ecosystem and human health need to be undertaken. Although opinion surveys like the one conducted within the working group can help to highlight perceptions of risk, more stringent analyses should regularly be undertaken to more objectively rank threats to health, track the progress of existing corrective actions, and better define emerging problems.

earth processes like climate regulation are at risk. Considering the nature and scope of the threat to all life, it is likely that a broad range of actions will ultimately be needed to reduce anthropogenically-driven environmental destruction, restore earth ecosystems, and ensure human survival as one species amongst others on earth. Still, it was the consensus of the group that some specific policy priorities seem evident. For example, to cope with continuing global environmental changes, industrialized countries such as Canada, the USA, and those in the European Union will have to contribute their share to international greenhouse-gas emission reductions, and make other meaningful investments to monitor and maintain ecosystem and human health. A large part of the necessary investment in mitigative and adaptive measures may justifiably come from economic sectors most directly associated with the causes or consequences of environmental disruption. Of course, individuals will have a pivotal role in instigating and supporting policy changes by adopting a new personal ethic oriented less towards consumption and more towards conservation and healthy lifestyles. In addition, the health sector (including local and national health agencies) will need to provide leadership by enhancing public awareness of health issues related to environmental degradation, by helping to identify public health priorities, and by helping to shape appropriate prevention and response policies. Importantly, actions should be implemented in collaboration with neighboring nations because threats to ecosystem and human health do not respect geopolitical boarders.

A strong-held belief among many participants was that the equitable development and consumption of resources within and among regions and countries should be a policy priority. For example, Apartheid in South Africa included among its many discriminative practices a dramatic inequality of resource distribution. Although for many years the World Bank measured progress by assessing earned annual income, they now evaluate the distribution of key resources, such as the number of homes and villages that are supplied with water and sanitation. In South Africa, the hope is to provide "the basics" and then let the community co-evolve with the environment. The South African constitution proclaims: "Some water, for all, forever." This simple statement captures a basic premise that surfaced time and again in our group discussions: that issues of equity and the environment are integrally related. With this in mind, our group concluded that a better collaboration between rich and poor nations is badly needed. Although this has been repeatedly requested in the past, it seems ever more evident that long-term improvements in the economic and environmental health of developing countries will not occur without a halt to the overexploitation of world resources by industrialized nations.

Even concerning issues of international equity, the group agreed that small-scale (individual and community) actions figure prominently as instigators of change. In many cases, the statement: "Think globally, act locally" is still vitally relevant. While most environmental impacts can have global implications, many

preventative and corrective actions have their roots at the local level. This is where individuals and communities can have the most control. This is where each person has a real chance to make a difference.

5. Barriers to effective action

Even though there is a growing awareness that human activities pose a mounting threat to natural and human populations, it seems unlikely that the changes needed to safeguard ecosystem and human health are imminent. Numerous attempts to reshape individual lifestyles and public policies (ranging from Earth Day to the Rio Summit) have occurred with increased frequency as worldwide awareness of environmental problems has grown. Still, tangible evidence of meaningful action to halt human-induced environmental harm and rebuild/nourish ecosystem and human health is scarce. Unfortunately, there are many reasons for inaction. Some were reviewed in the previous chapter. However, through group discussions it was suggested that overcoming certain crucial barriers might have enhanced importance because they disproportionately deter action and impede change. These five barriers are described below.

5.1. Sustenance needs

In many developing communities, the primary and immediate goal is short-term survival. Understandably, if fundamental sustenance needs for food, water, and shelter are not met, long-term concerns about education and environmental quality take on a low priority. For example, in Vietnam, deforestation is fast occurring. As explained by one of our Vietnamese participants, "There is not enough water for rice production or drinking: there is a clear relationship between all these activities. You can't ask a hungry person to save something for tomorrow. People have to eat every day ... What is a solution here?" Indeed, this is one of the reasons why equity issues figure so prominently in the debate concerning the environment and health worldwide. Social inequities that deprive people of the basic necessities of life often force them to establish in marginal, fragile, and less productive ecosystems where local patterns of resource use and exploitation (e.g., rapid rotations of slash and burn agriculture) can be harmful to both ecosystem and human health in the long term. Perspective is everything. When one is well fed and has the other basic necessities of life fulfilled, it can be all too easy to condemn unsustainable resource use. But what would *you* do if faced with uncertain prospects for short-term survival? Clearly, a major obstacle hindering long-term planning and management in many regions is the persistent inability of impoverished, often rural peoples to meet basic sustenance needs. In these regions, cycles of poverty and human deprivation must be broken if long-term ecosystem health is to be improved.

therefore frequently impart an enormous influence on public opinion. By enlisting the help of these leaders, governments and others could tap into an established communication network and more effectively spread environmental health information (including indicators of ecosystem health) to local communities. Group members cautioned, however, that religious leaders are not uniformly viewed as unbiased protectors of the public good. Especially when aligned with repressive governments or movements, religious leaders might not retain public confidence. Open affiliation with religious leaders under these circumstances could actually hinder the promotion of ecosystem health programs.

Educators represent another likely user group for ecosystem health data. Indeed, through the course of discussion it became evident that the linkage between scientists and primary and secondary school educators has already been successfully developed in some locations. One participant from Vietnam reported that scientists in his homeland have long recognized that the school children of today are the citizens and decisionmakers of tomorrow. As a result, scientists there initiated an active program of involvement in community-based environmental education. Similarly in Canada, several programs have targeted school children and citizens of all ages for education efforts (e.g. Adopt-A-Stream; Naturewatch, a community-based monitoring program launched in 2002 by the Ecological Monitoring and Assessment Network of Environment Canada and the Canadian Nature Federation, which includes programs such as Plantwatch, Frogwatch and Icewatch). The involvement of school children within the USA in acid rain monitoring networks provides another noteworthy example. In recognition of the successes of past but thematically more limited efforts, it was suggested that a more comprehensive program be developed to collect broad-based ecosystem health data using area schools. Local students and teachers would collect data that could be used to generate ecosystem health indicators that over time could provide community, regional, national, and world leaders a detailed gauge of ecosystem health trends. Although an ambitious undertaking, the development of such a program could be fostered through concerted grass-roots efforts instigated by science professionals and educators. For example, in industrialized countries, many of us serve on school boards where we can influence science curricula and the hiring of teachers who would utilize such a program.

Finally, another group that should have an interest in environmental health data is the media. Their professional roles (to inform the public of issues that influence their lives) make them obvious target groups. Furthermore, journalists often hold the interest of policymakers, likely facilitating communication to this important group. However, it was cautioned that journalists are not always "scientifically literate" and that scientists are frequently not "media smart". The nuances and limitations of scientific information are often difficult to relate, especially in instances where "details" seem to obscure or confuse a "story". Still, it is evident that clear communication and cooperation among a range of professions and users

will be needed to fully utilize the potential value that indicators of ecosystem health might someday provide.

7. Conclusions

Through the course of discussion, the working group covered a broad spectrum of topics within the overarching subject of ecosystem health and human health. The five questions the group sequentially addressed, provided a needed structure, and helped guide joint progress. However, even with this guide and overlying structure, discussions were far ranging. In particular, the considerable diversity of participants greatly enriched the breadth and scope of debate.

Despite the broad theme, open debate, and the rich diversity of participants, the fundamental level of consensus among participants was astounding. Anchoring this consensus was the knowledge that ecosystem and human health are intricately interdependent and that human activity is increasingly threatening both. Indeed, participants spent a considerable amount of time detailing the mounting evidence of anthropogenically induced ecosystem dysfunction and the associated impacts on human health. However, as the guiding questions for debate and this resulting chapter indicate, an even greater proportion of our attention was occupied with considerations of appropriate response. The group was uniformly convinced that unbridled human activity was threatening the intricate web of biological and ecological processes that support all life. Participants seemed equally certain that this threat was so grave and immediate that broad-based and timely action was not only warranted, but imperative.

Many participants commented that "we don't manage the ecosystem, we can only manage ourselves." Because local and even global environmental issues ultimately result from the additive effects of our individual but cumulative decisions and actions, solutions to these problems should address individual beliefs and behaviors as well as cultural norms and public policies. Although the group shared this unified perspective of the serious threat posed to ecosystem and human health, members were also struck by the realization that many other inhabitants of the earth did not share this perspective. Participants openly wondered: could this be the root of the environmental problems we face?

As detailed earlier, the barriers to change are many and also span a range of scales. However, time and time again, it was the group's conclusion that education and communication were the primary tools needed to overcome these barriers and foster meaningful personal and societal change. Because the goal of education and communication efforts is ambitious (i.e., to expand perceptions of the interdependency of ecosystem and human health), innovative methods will need to be deployed because the goal is not just to communicate facts, but rather to help individuals reevaluate ingrained attitudes and behaviors.

Many shifts in attitude are needed. However, some fundamental starting points seemed evident. For example, Public NIMBY (Not In My Back Yard) perceptions

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