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Human Health in Ecosystem Health: Issues of Meaning and Measurement

Great Lakes Science Advisory Board. Workgroup on Ecosystem Health. Subgroup on Measuring Ecosystem Health

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ISSUES OF MEANING AND MEASUREMENT

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DISCLAIMER

This report to the Science Advisory Board was carried out as part of the activities of the Workgroup on Ecosystem Health's subgroup on Measuring Ecosystem Health.

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"When I use a word," Humpty Dumpty said in rather a scornful tone, "it means just what I choose it to mean — neither more not less."

"The question is," said Alice, "whether you can make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master — that's all."

Lewis Carroll

"The tendency has always been strong to believe that whatever received a name must be an entity or being, having an independent existence of its own. And if no real entity answering to the name could be found, men suppose... that none existed, but imagined that it was something peculiarly abstruse and mysterious."

John Stuart Mill

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EXECUTIVE SUMMARY

The purpose of this monograph is to examine definitions of ecosystem health and explore their implications for including considerations of human health in ecosystem science. It begins by setting the context of the ecosystem approach, particularly from Great Lakes documents, although the relevance of the Ottawa Charter and WHO strategies is recognized (section I). This approach and ecosystem health point to the inescapable connection between science and society (or values, or politics). This connection is seen in the debate over whether actions concerning ecosystem health should be based on "proof" or "prudence." Given the contested nature of science and action, section II explores the roots of ecosystem science in terms of the nature of ecosystem, recognizing three characterizations, ecosystem as entity, as perspective, and as notion. It goes on to introduce, define and discuss ideas of ecosystem health and integrity, concluding that the terms not only have scientific but also metaphoric significance. The power of metaphor is analyzed and caution must be exercised with scientific notions such as "ecosystem health" that resonate with societal meaning. Such meaning makes measurement difficult and the section closes with a discussion of the relations between models and metaphors, with the need for indicators to monitor progress toward desired outcomes and with the recognition that culture limits our choices in both tools and meanings of measurement.

There follows a brief discussion of the relations between human activity and ecosystem health (section III). This section highlights historical perspectives and recent responses to the increasing complex relations between people and environments. It stresses the need to recognize the role of human innovation and adaptability in these relations and the fact that human valuation of the ecosystem or environment varies over time and space and in relation to other core-values. This recognition must be set against the different visions of ecosystem that currently give it pre-eminence.

Another significant core-value or interest is human health. Its protection may be seen as the most important goal of environmental management. In some ways, human health is part of ecosystem health, because humans are part of the environment (section IV). There is a long tradition in examining these relations which are seen as fundamental dimensions of the human condition. But human health may be defined in many ways, narrowly in two: negatively as the absence of disease or illness, and positively as the presence of conditions conducive to human health and well-being. These definitions then set the scene for two major parts of section IV concerning respectively the environmental burden of illness, in which despite limited evidence an assessment is made of the role of environmental exposures for specific health outcomes, and the environmental conditions for well-being, in which the broad determinants of health are laid out. In some respects, another difficult task awaits: that of bringing together "the burden" and "the conditions" in the context of core-values and human needs and interests. Section V is only partly able to achieve this in reviewing the presence status of indicators for environment, human health, the environmental burden of illness, and perhaps most directly, sustainability. With respect to the Great Lakes, many categories of indicators have been developed. The section ends with a discussion of criteria for indicator suitability and selection. What makes a good or poor indicator? We argue that there are two sets of criteria for determining this — a scientific one and a use-oriented one.

In the final section (VI), seventeen recommendations are put forward, derived from the reviews and discussion in the monograph. They range from the specific involving the assessment of particular environmental burdens and exposures to specific toxins among populations, the monitoring of established environmental health outcomes and state of the environment reporting to the more general concerning identification of appropriate human health and well-being indicators relevant to ecosystems/environments with due attention to selection and suitability criteria and to the balance between proof and prudence. We also recommend value clarification over "ecosystem health" and take note of a caution, namely that connectionist thinking may limit our capacity to act in limited, but important ways, one of which is to develop good indicators of human health in ecosystems.

I.

INTRODUCTION

The purpose of this monograph is to examine definitions of ecosystem health and explore their implications for carrying out science on ecosystem performance, especially with respect to the inclusion of human health considerations in ecosystem health. The very term "ecosystem health" seems to imply or at least call out for such considerations. In fact, the International Joint Commission (IJC 1991) points out that there are three important ideas behind the management of the Great Lakes region in terms of sustainable development. These are self-maintenance of ecological systems, sustained use of the ecosystem for societal purposes and sustained development for human welfare. The last-named "includes not only medical issues relating to human health but broader issues concerning the potential for human development, including the perceived quality of life" (IJC 1991, 6). It is suggested that this rationale is the least considered from a management perspective. If this is correct, we would argue that there is a danger of subsuming these issues as dependent parts of the health of the ecosystem rather than worthy of independent consideration. In section II, we explore some of the outcomes arising from subsuming human health and well-being in "health of ecosystem."

This monograph is, however, written from a perspective that is supportive of the ecosystem and ecosystem health perspectives. The emphases on ecological integrity, self-sustaining ecosystems, natural ecological boundaries and holistic orientation toward management (see Thomas et al. 1988; Mackenzie 1993; Allen et al. 1993) are appropriate. Generically, it may be seen as part of connectionist thinking which sees things in terms of networks of connected units which excite or inhibit other units (see Bechtel and Abrahamsen, 1991). Such is "ecosystem." Specifically as Mackenzie (1993, 145) notes, "the ecosystem approach has emerged as the latest effort in a long trend toward more comprehensive and integrated management..." Lee et al. (1982) chart the early attempts to initiate such an approach, arguing that their common features include:

1. a focus primarily on ecological phenomena, rather than on the conventional and historically dominant political, engineering, economic, or accounting perceptions;
2. spatial boundaries within which management plans are formulated, which reflect some aspect of ecological integrity within the boundaries;
3. a balanced, integrated combination of mapping, monitoring, modelling, and adaptive management case studies to convey, analyze, and update ecosystem information;
4. cohesive, self-regulatory structure and function of ecosystems involving stable phases or states or equilibrium, and thresholds or limits of stress tolerance of those states; and
5. ecosystem response to (i.e., change from) human activities, with responses to different uses often interacting synergistically. (Lee et al. 1982, 516).

But in these early documents, we see the application of metaphor:

> *This ecosystem approach is based on a man-in-system concept rather than a system-external-to-man concept inherent in the 1972 Great Lakes Water Quality Agreement. Incorporation of this approach within the advisory and management functions of the Commission and Parties, respectively, necessitates political recognition of the Great Lakes basin as an Ecosystem composed of the interacting elements of water, air, land and living organisms, including man, within the basin. It further necessitates explicit recognition of exchange of materials such as atmospheric pollutants into and out of the basin in biospheric perspective ... It directs the efforts of the parties and Commission toward treatment of the patient (the Ecosystem) rather than the symptoms or disease. It relates the biological and technical activities of man in the carrying capacity of the Ecosystem, linking the human body to the biosphere.* (IJC 1978, vii).

We shall argue that these applications require careful attention for the practice of science and the understanding of the relationship between science and politics. It is perhaps more accurate to speak of health of ecosystems (or status of ecosystems) rather than ecosystem health. But over the past decade, human health considerations have been explicitly coupled to those of the ecosystem. As the IJC (1991, 28) puts it "the connections between the conditions of the natural environment and human well-being have become less immediate and obvious in the past century." But in advocating the development and application of "socioeconomic indicators," the Commission goes on:

> *these indicators of linkage between humans and the non-human components of their environment can assess not only the effects of environmental degradation on human well-being. They provide evidence for the social and political relevance of ecosystem objectives that lack a human face.* (IJC 1991, 29).

In this respect, measurement and indicators are seen as having a direct political purpose as the model of ecosystem-human relations being adopted and used is seen as too important to be without public support. We discuss these linkages between measurements and norms in section II. There are three ways of linking socioeconomic "health" to ecosystem health: reasonable human use of resources; favourable public perceptions of quality of life and environment (both discussed in section III) and human health (section IV).

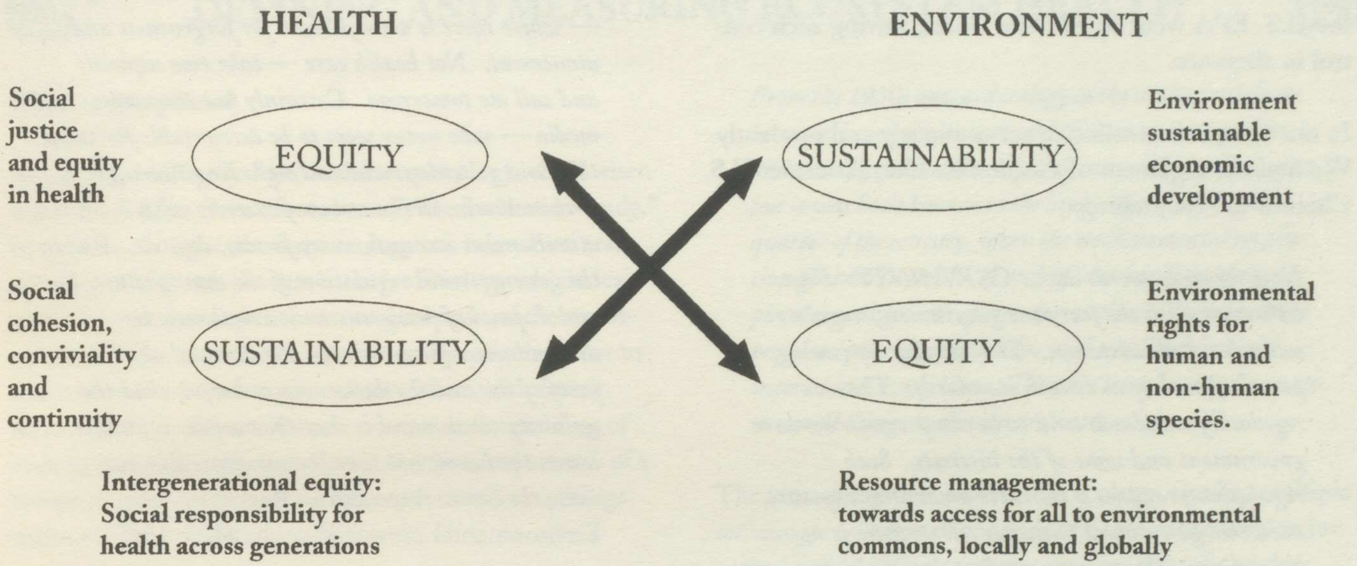
Attempting to combine human health and ecosystem health in one framework is also recognized as a preferred strategy by WHO (1987), which develops a procedure within the overall framework for environmental health impact assessment (EHIA). The strength of this suggestion still lies primarily in its taking forward the debate grounded in the Ottawa Charter for Health Promotion in that "the fundamental conditions and resources for health are peace, shelter, education, food, income, a stable ecosystem, sustainable resources, social justice and equity" (CPHA 1986). In this, we see that the reasons for combining environment and health or ecosystem health and human health are largely moral — supported by attachment to particular core-values. At one level it is important to see how the values and goals of the health-oriented Ottawa Charter relate to those concerning the environment. Brown (1994) has attempted to match the frameworks of Ottawa Charter and the Brundtland report (Table I) and link the goals and values that sustain them (Figure I).

In examining the significance of ecosystem health for humankind, there resides the inescapability of politics (or values) in science. While science is carried out objectively, it is never, at root and in its assumptions, value-free. Recognition of and openness about values are crucial as is recognizing the connection between science and society. Science is of course part of society. And further, the nature of that relationship colours what questions are asked, how they are asked and the ways in which they might be answered (section II). This is easily demonstrated by seeing how different societies treat the same

Table I. Matching Public Health and Environment Frameworks to Health and Environment Goals.

	Coordinating policy	**Enhancing environment**	**Enabling strong community action**	**Strengthening individual skills**	**Reorienting services**
OTTAWA CHARTER					
Health Goals	Equity social justice	Monitoring sustainable social environment	Social advocacy	Lifestyle changes	Treat cause not symptoms of disease
Environment Goals	Global sustainability	Monitoring sustainable physical environment	Issues advocacy	Individual changes in resource use	Treat origins, not outcomes of environmental pressures
BRUNDTLAND ACTION PLAN					
	Investing in an equitable future	Assessing environmental risks	Dealing with the risk through the whole community	Making informed individual choices	Getting at the sources of risk

Figure I. Linking Health and Environment Goals: Equitable Sustainability and Sustainable Equity:



Source: Brown (1994,5)

problem e.g., the centralized (France) and decentralized (Sweden) ways of dealing with nuclear waste (Cook et al. 1991, 2) or the establishment of different risk parameters for dioxin in Canada and the U.S. (Harrison 1991).

The connection between science and society is particularly interesting for ecosystem health or environment-health in general. There are in fact at least two sciences. There is that representing the ecosystem perspective concerned about the possible consequences of past and present degradation and political inaction: a science apparently willing to extrapolate from ecological data and animal studies to human impacts. Then there is that representing a cautious approach to scientific evidence as practised in epidemiology which wishes to weigh evidence so that it can be concluded unequivocally that a particular health outcome derives from a particular environmental exposure. Both types of science practise excellent science — they differ on weight of evidence and willingness to extrapolate.

Indeed, they represent different approaches to evidence: the one (e.g. epidemiology) demands proof, whereas the other (e.g. ecology) demands action on the basis of prudence.

There has been recent advocacy of adopting a prudent position as our review on human activity and ecosystem health (section III) will attest. In 1992, the IJC urged the adoption of a "weight of evidence" approach which is meant to take into account the cumulative weight of many studies. If taken together, the amount and consistency of evidence across a range of circumstances and substances are judged sufficient to indicate a strong probability of linkage and/or injury, the existence of a causal relationship is made (IJC 1992; 1994; 1995). Further, the virtual elimination strategy adopts a precautionary principle. Environmental policies and measures must anticipate, prevent and attack the causes of degradation. Where there are threats of serious or irreversible damage, lack of scientific knowledge and certainty should not be used as a reason for postponing measures to prevent environmental degradation and to sustain the ecosystem (Virtual Elimination Task Force 1993).

We recognize the concern of scientists who argue for the burden of proof to be demonstrated. There is a danger that underpinning precaution is the notion that "my science is better than yours." Further, if precautionary science is linked to political action through shared paradigms and world-views, it may be unstoppable even if contradictory evidence is later found. And this discovery of the counterfactual is possible. In 1978 the U.S. Surgeon-General commented that "noise is more than just a nuisance. It constitutes a real and present danger to people's health... Must we wait till we prove every link in the chain of causation?... In protecting health, absolute proof comes late. To wait for it is to invite disaster or to prolong suffering unnecessarily" (reported in Taylor and Wilkins, 1987). Except for industrial noise, the burden of proof never arrived. While the public may be annoyed about noise it seldom results in hearing loss. But prudence resulted in some noise control measures, although the U.S. EPA went on to other issues, leaving such control in abeyance.

In our view, it is sensible to act cautiously and prudently. We find the argument of Gordon K. Durnil, former U.S. Chair of the IJC, telling:

> *Now for some words about CERTAINTY. First, let"s start with the fact that governments regulate some chemical substances. They do that by issuing permits based upon certain standards. The regulatory standards tend to be compromises between government and some of the interests. Such regulation presumes a tolerable amount of exposure, even though eminent scientists tell us there is no human assimilative capacity for some of those substances...*
>
> *Whenever a suggestion is made to protect health, especially human health, we hear about bad science and the lack of scientific certainty. We heard those claims in the breast implant discussions, and we heard it again recently as the tobacco industry testified before Congress. Still governments demand absolute scientific certainty of the cause/harm linkage, before changing a standard. And industry denies responsibility because absolute certainty of the causal relationship to the harm has not yet been found. Think about that. What other aspect of our lives demands such certainty before exercising caution? Not the law — we convict people on the subjective judgment of just twelve individuals. Not education — where 70% can be a passing grade. Not religion — where there is always room for forgiveness and atonement. Not health care — take two aspirins and call me tomorrow. Certainly not the news media — who never seem to be accountable for what they said yesterday. Accounting? Engineering? Architecture? All have room for error, with miscellaneous accounts, sway factors, etc., etc. But in the governmental regulation of the manufacture, use and disposal of persistent toxic substances, we demand scientific certainty. We demand absolute proof of the causal relationship to harm. And the certainty we demand is that the onerous substance causes the harm, not that the substance does not cause the harm.* (reported in Rachel's Environmental Health Weekly #423; 1995).

But as we act prudently, we must be open to scientific evidence that could change our minds. Indeed, we argue that we require criteria for assessing prudence, i.e. when it is right to act. Is there an environmental health equivalent of the pass/fail grade in education? We shall thus recommend attention be given to the weight of evidence criteria and the evaluation of "prudent to act" claims through decision-rules (see section VI). We must, however, first review the issues. In the next section, we examine the implications of defining ecosystem health in particular ways and the bases of measurement. There then follows brief reviews of human activity and ecosystem health (section III) and the implications of including human health in ecosystem health (section IV). We then examine the ways that are available to measure ecosystem health and human health status (section V). We conclude with a set of recommendations (section VI).

II.

DEFINING AND MEASURING ECOSYSTEM HEALTH

What is ecosystem?

At the heart of "ecosystem" is the term ecology which when traced back to its Greek roots literally means "house-study." In modern thought, the term ecology can take on several meanings. It stands for that branch of biology which deals with interrelationships between organisms and their environment. The word is also used in a more popular sense to indicate concern for the protection of the environment. Allison (1991) adds a third value-laden understanding of ecology: a belief in the practical and *ethical* importance of a holistic understanding of the interactions of living things with each other and the environment.

For industrialized nations Worthington (1983) describes the twentieth century as the ecological century (the eighteenth century was marked by the enlightenment and the nineteenth by industry). He explains the origin of the ambiguous definitions of ecology that have come to be broadly accepted:

> *From the 1930s onward ecology as the mutual relations between living organisms and their environment slowly and steadily gained the respect of conventional biologists, but it was little known to the lay public until the third quarter of the century, when the environmental revolution got into its stride. A main factor in this was the phenomenal growth of communications. Travel became popular: photography, radio, and television brought interest into every home. Then the term "ecology" came to mean all things to all men and women.* (p. viii)

The term ecosystem, like its root ecology, also has multiple meanings — it is at once an identifiable natural region (an entity) and a particular approach to ecology. Schrader-Frechette and McCoy (1993) have recognized the variation in the descriptions of ecosystem as entity and have compiled a chronology of definitions to show the lack of consensus among ecologists on meanings of several key ecological terms including "ecosystem" (Table II). The notion that the

Table II: Definitions of Ecosystem

Tansley (1935)	The fundamental concept appropriate to the biome considered together with all the effective inorganic facts of its environment. In an ecosystem, the organisms and the inorganic factors alike are components which are in relatively stable dynamic equilibrium.
Hanson (1962)	The community, including all the component organisms together with the abiotic environment, forming an interactive system.
Odum (1963)	The community and the non-living environment functioning together.
Shelford (1963)	Habitat and community as an interacting unit.
Knight (1965)	Includes all of the living and non-living components of the environment, so that the entire world could be considered a giant ecosystem.
Wilhm and Dorris (1968)	Natural unit composed of abiotic and biotic elements interacting to produce an exchange of materials.
Whittaker (1970)	A community and its environment treated together as a functional system of complementary relationships, and transfer and circulation of energy and matter.
Krebs (1972; 1985)	Biotic community and its abiotic environment; the whole earth can be considered as one large ecosystem.
Pianka (1978; 1988)	The climate, soils, bacteria, fungi, plants, and animals at any particular place together.
Brewer (1979; 1988)	The community plus its habitat; the connotation is of an interacting system.
McNaughton & Wolf (1979)	All the organisms and environments in a single location.
Smith (1980; 1986)	Same as Tansley (1935)
Lederer (1984)	All organisms, the surrounding environment and their interactions in a stable situation.
Begon et al. (1986)	Comprises a biological community together with its physical environment.
Ehrlich & Roughgarden (1987)	The biological community in an area and the physical environment with which it interacts.
Kay & Schneider (1994)	A collection of interacting biological entities combined with the physical environment in which they live, which is perceived to act as a whole.

Source: Amended from Schrader-Frechette and McCoy (1993) ecosystem as an entity includes both the physical and the biological is the common ground for these definitions. The ambiguity of the "ecosystem as entity" arises when referring to a particular bioregion or ecosystem type. "Ecosystem" has been used to describe the entire world (Knight 1965), the Great Lakes (IJC 1991), forests (Reichle 1981) and aquatic environments (Rapport 1995). Drawing boundaries around these spatial scales is, furthermore, somewhat arbitrary given that ecosystems are open systems — inherently interconnected to adjacent ecosystems (Rapport 1989) making scale dependence one of the difficulties in assessing ecosystems and health of ecosystems. Further, open systems may be loosely or tightly structured and it repays close attention to determine how much loosely-interrelated components should be taken into account — the degree of "coupling" is vital (see Perrow 1984).

Arthur Tansley, a British ecologist, is credited with the origin of the term ecosystem although Pomeroy et al. (1988) claim that the concept of hierarchial levels of integration had been circulated within biology circles many years before that time. Bocking (1994) explains that the term ecosystem provided an important orientation for ecologists:

> *The ecosystem was one of special interest to ecologists. As the basic unit for nature... the ecosystem asserted the unity of ecology, while distinguishing it from the study of both individual organisms and inorganic systems.* (p. 12)

Ecosystem as perspective is a second characterization. For ecologists, there are two fundamental ways of approaching the organism-environment relationship. The first is the "population-community" approach which focuses on the growth of populations, the structure and composition of communities of organisms, and the interactions among individual organisms (O'Neill et al. 1986). This approach tends to view ecosystems as networks of interacting living populations, so in effect, "the biota are the ecosystem" (p. 8) while the non-living components are understood to be external influences or the backdrop/context in which biotic interactions occur. The second is the process-functional approach emphasizing biophysical models of energy flows and nutrient cycling (e.g. Kay 1991).

These dual analytical approaches, respectively, introduce such a vast number of possible states or elements that complete characterization of an ecosystem is never possible (Regier 1993). King (1993) notes that the common ground for both approaches is the emphasis on interactions. The former emphasizes biotic interactions, the latter fluxes of matter and energy. In this way, he explains, "ecosystem may be identified as a perspective, a particular way of looking at the biota and environment of an area" (p. 22). In this, ecosystem becomes a mental construct as well as (possibly) a concrete entity.

If ecosystem can become mental construct as well as concrete entity, a third approach becomes possible. It is the notional or abstracted ecosystem, well-expressed by Allen and Hoekstra (1992) who argue that the observer uses a filter to engage the world. This filtering makes observation arbitrary, notional, abstracted. It involves not only definitions and identifying critical changes but also the nature of measurement and the data collection process. In some ways, the ecosystem is the system our measuring tools and information gathering techniques allow us to see. Put slightly differently, the human impact on ecosystems is dependent in part on how as well as what we observe (Bandurski 1994). This idea of notional or abstracted ecosystem is closely linked to issues of meaning of measurement (see below) and is important for policy as the abstracted system becomes the system of interest or the problem-at-hand.

In policy-oriented research, the ecosystem has been approached differently. Slocombe (1993), in an essay on the links between planning and sustainable development, has synthesized the core characteristics of ecosystem approaches from disciplines as varied as anthropology, psychology, human ecology, and environmental planning. For Lee et al. (1982) the ecosystem approach "involves environmental holism: a concern for whole-ecosystem health and an attempt to understand man[sic]-nature interactions which enhance or degrade that condition." (p. 505) These interactions are key to the IJC approach in that ecosystem refers to an ecological system occupying a particular place and time with emphasis given to system description of interaction biota and the environment, including explicitly human activities (Allen et al. 1993). Further, ecological integrity — highlighting scale dependency — is seen as the way of assessing whether interactions enhance or degrade ecological conditions (see Rapport et al. 1985).

Ecosystem Integrity and Health

But can ideas about integrity and health be sensibly and legitimately applied to ecosystems? The health idea has a long history and is being increasingly used in environmental literature (see Figure II). Rapport (1995) points

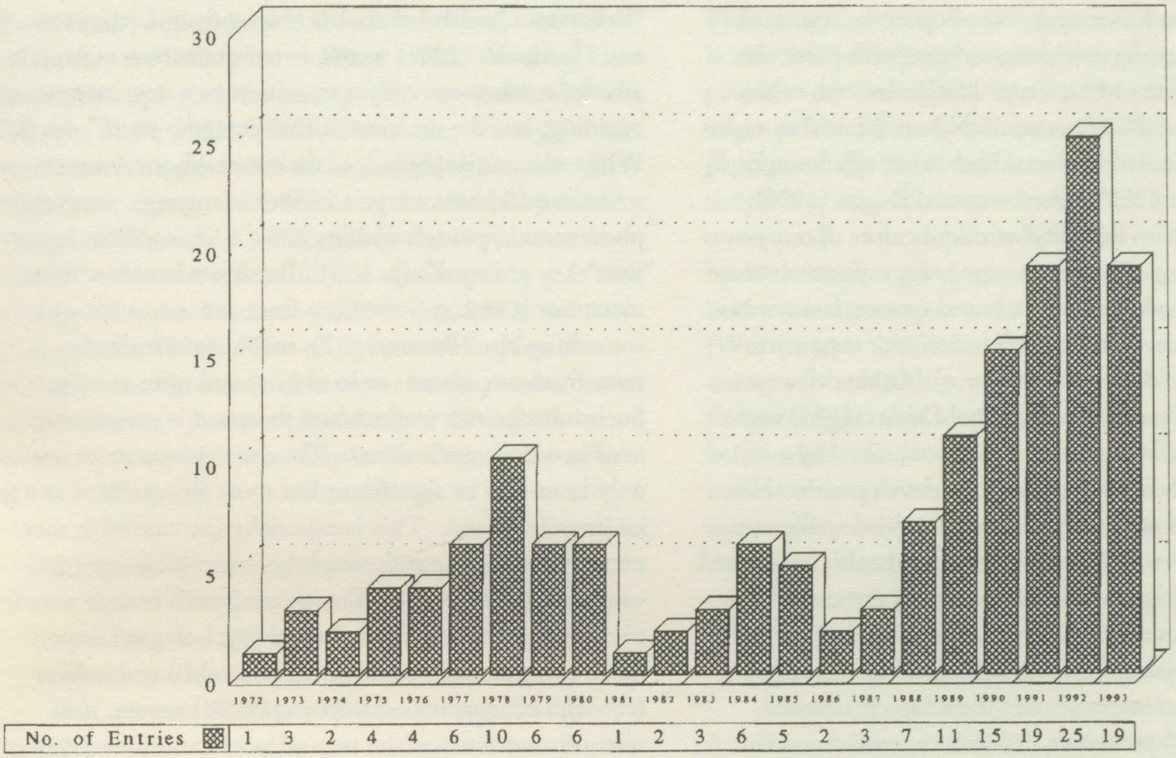


Figure II. Entries in Enviroline: Using Terms "ECOSYSTEM" and "HEALTH"

to Hutton's references to the health of nature. While ecosystems are not analogous to organisms, they are like all complex systems in that they involved mechanisms of self-regulation necessary to maintain system integrity and resilience. Health is thus used metaphorically.

Callicott (1992) traces land health to Aldo Leopold (a conservationist scientist in the late 1930s and 40s). For Leopold, the notion of land health was associated with the structural *integrity* and the continuity or *stability* of biotic communities over long periods of time. It was Leopold's belief that organisms and ecosystems have one very fundamental thing in common: the capacity for self-renewal (Callicott 1992). From Leopold's metaphor, Callicott creates a definition of ecosystem health suggesting that ecosystems displaying order, stability, and continuity are healthy and that maintaining land health is as possible and fundamental as the maintenance of human health or the health of a nation's economy. Callicott writes:

> *Ecosystem health is a condition of internal order and organization in ecosystems, which no less than analogous conditions of* ***body, soul and society*** *are both intrinsically good and objective* (and specifiable in principle). (our emphases) (p.43)

Similarly, the definition employed by Haskell et al. (1992) incorporates Leopold's concepts of stability, sustainability and self-renewal:

> *An ecological system is healthy and free from* "distress *syndrome" [the irreversible process of system breakdown leading to collapse] if it is stable and sustainable—that is, if it is* active *and maintains its organization and* autonomy *over time and is resilient to* stress. *Ecosystem health is thus closely linked to the idea of sustainability, which is seen to be a comprehensive, multiscale, dynamic measure of system resilience, organization and* vigor. *Accordingly, a* diseased system *is one that is not sustainable and will eventually cease to exist.* [our emphases] (p. 248).

But there have been many attempts to define ecosystem health or desirable ecosystem states. As Rapport (1995) points out, these definitions range widely from very broad definitions which incorporate bio-physical, human and socio-economic components (e.g. Rapport 1992) to definitions focusing primarily on the biophysical aspects (e.g. Costanza 1992) to those which focus on a single indicator within the biophysical domain (e.g. Kerr and Dickie, 1984). Many definitions are based on "effects" or "impacts" of stress on ecosystems — focussing on cumulative impacts of stresses both temporally and spatially.

Some definitions however are based upon the source of stress itself, focussing on risks associated with particular stresses (e.g. Minns 1992; Suter 1992). Indeed, other approaches make use of terms other than "health" to evaluate ecosystem transformation under stress, e.g. "integrity" (Karr 1993; Kay 1993). Steedman and Regier (1990) evaluate "ecosystem integrity" with indicators of ecosystem breakdown, many of which are signs of ecosystem distress (e.g. increased dominance by selected species, less symbiotic interactions and the loss of resilience or capacity to rebound from an external stress force). Others view nature-society interactions negatively. Odum (1985) suggests that stressed ecosystems are characterized by a reversal of trends found in ecosystem development. His analysis includes many of the signs of ecosystem distress. Schaeffer and Cox (1992, 159) state that health is achieved when functional ecosystem thresholds are not exceeded. Here threshholds are defined as "any condition (internal or external to the system) that, when exceeded, increases the adverse risk to maintenance of the ecological system." Schindler (1990) provides a detailed account of experimental results of acidification in freshwater systems, showing a sequences of changes or abnormal signs of ecosystem structure and function as acidification proceeds. Smol (1992, 51) defines a healthy ecosystem as an "ecosystem that existed prior to cultural impact." Health may also be assessed in terms of resistance to disease. Despite this variety, Rapport (1995) concludes that there are three properties at the core of ecosystem health: the absence of distress syndrome; resilience or counteractive capacity; and risk factors.

Use of Metaphor

In defining ecosystem health, "health" is used metaphorically, despite the problems with defining health itself (see section IV). In general terms, human health is more easily seen as the absence of disease rather than the presence of conditions that constitute wellness. Parallels are then drawn between the absence of disease and the absence of degradation or ecosystem distress. Although human health is not usually part of the ecosystem health considerations, the health analogy is powerful and leads to eliding human health concerns with those of the ecosystem without careful analysis. Thus human health is damaged if the ecosystem is "degraded" despite the apparent incongruence of tumours on fish and human well-being. Such is the power of metaphor.

Metaphors are linguistic phenomena where words normally associated with one object are applied to another. "Ecosystem health," then, borrowing from Livingstone and Harrison's (1981) terms, is an interaction metaphor which "involves not only a transition to a new category of meaning, but the creation of that category itself." (p. 96) While some metaphors lose their metaphorical nature over time and become part of literal language, most metaphors remain pure, "revealing their meanings afresh each time they are used" (p. 100). But in its broadest sense, metaphor is seeing something from the viewpoint of something else (Brown 1977), involving transferring a term from one system or level of meaning to another. Such transference works when the word is consciously used in a different context. Thus metaphors must not only intend to be significant but must also pretend not to be literally absurd. This is especially the case with root metaphors which put forward fundamental images and values about the world. Ecosystem health is such a metaphor, with it having fundamental psychological importance being linked to self (through health) and holism (through ecosystem). As Strong (1994) argues, non-scientific accounts of the natural world and the adoption of ecological terms into everyday language are important in that they "provide a language of engagement with nature" and thus they contribute "information about a tangible, publicly accessible world." (p. 90) "Ecosystem health's" power lies in its ability to evoke action and concern about environmental degradation given that most of us can relate to a state of ill-health in our own bodies (Ehrenfeld 1992). Buttimer (1993, 156), in her discussion of the roots of organicism as a world-view, argues:

> *The powerful appeal of organism as root metaphor of reality may be explainable in terms of its grounding in the most universal and intimate experience of all humans, that is, the experience of one's own body.*

The purpose of the ecosystem health metaphor is then not to appeal to literal or completely rational thinking. Instead the term, as metaphor, "points to the very process of learning and discovery, to those analogical leaps from the familiar to the unfamiliar which rally imagination and emotion as well as intellect." (Buttimer 1993, 78) If we think of metaphor, in general, as the "intellectual link between language and myth" then its function becomes one of helping to preserve and create "knowledge about actual and potential connections between different realms of reality." (Buttimer 1983, 78) Human health is ecosystem health, ecosystem health is human health.
But let us unpack the literal components of the metaphor. Norton (1992) explores some of the pitfalls inherent in relying on analogy and metaphors. Ecosystems cannot,

for example, announce that they are sick and then tell when they are feeling better (Page 1992). Much of the literature employing the concept of ecosystem health (e.g. Rapport 1989; 1992; CPHA 1992; Allen et al. 1993) is furthermore suggestive of ecological principles of: 1) organismic theory which has been abandoned by most ecologists (Ehrenfeld 1992); and 2) stability, succession, diversity which have been further challenged by the "new" ecology (Shrader-Frechette and McCoy, 1993; Zimmerman 1994). The metaphor also implies that ecologists can distinguish between a healthy and a diseased ecosystem just as a physician can distinguish between a patient who is healthy or ill. But, as Ehrenfeld (1992, 137) explains:

> *[if] communities have fixed identities, [if] they are normative like organisms, we can easily apply the normative idea of health to them: if they are functionally and structurally similar to their abstract ideal, they are healthy; if they deviate significantly they are sick. If the idea that communities have a normative, equilibrium position, a balance point, were still widely accepted, then the idea of ecological health would pose few problems ... but ecological concepts change ... no longer are communities considered normative.*

Kelly and Harwell (1990) lament that the analogy of ecological health to human health is strained given that ecosystems are far more complex than human metabolism; exposure of an ecosystem to external disturbance often means differential exposure to only loosely connected parts of the system. Human tissues and organs, on the other hand, are strongly internally coordinated and highly interdependent.

Even with a characteristic set of normative ecosystem ideals, the health concept would still prove problematic. Just as the definitions of human health can vary between individuals, across cultures and over time, so can they vary for ecosystem health. There is thus a scale dependency with ecosystem health. This is recognized by researchers but if recognized in the public domain, the metaphor loses power and we are left with an uneasy combination of anthropomorphic condition and biotic environment. Many chronically ill individuals who function barely adequately on a day-to-day basis describe themselves as healthy. Similarly, the health of aquatic ecosystems could be defined as having good quality drinking water or beaches open for swimming or even a productive fishing industry, despite some "distress."

Should we therefore dismiss the metaphor "ecosystem health"? Not only is this not practically or reasonably possible (others continue to use it) but it also denies its importance. Fine and Sandstrom (1993) contend that people actually see and understand their world through simple slogans and metaphors like "ecosystem health" — not through any complicated theories. The ecosystem health metaphor provides a commanding image tapping both environmental concern in our ecological times (Worthington 1983) and the *normative* and personal nature of the health concept. Fine and Sandstrom (1993) further suggest that ideology (defined as "a linked set of beliefs about the social or political order") is based largely on sets of images and metaphors that can effectively draw upon widely held normative beliefs. In their interpretation, then, metaphor can be employed as an effective instrument in the promotion of ideology:

> *Metaphor . . . is a handy tool for the ideologist in presenting pictures of "how things are" and of "how they might ought to be" — pictures that both resonate with people's lived experience and offer them an appealing sense of how they can and should live. Through metaphorical images, the ideologist mobilizes images that enable people to experience the "moral."* (Fine and Sandstrom, 1993, 27)

Scientists respond to metaphor in much the same way as the general public (Gieryn 1983). They are guided by dominant cultural images in deciding suitable topics for research and in constructing limits around the "boundaries of science," which are of course shaped too by how observations can occur. The ecosystem health metaphor has indeed served as a point of departure, and as an important heuristic tool for scientific investigation into environmental *diagnoses* and *prescriptions* in general and the state of the North American Great Lakes in particular. For both scientists and the lay public, the ecosystem health metaphor provides a method of common engagement, a "metaphorical resource" (Fine and Sandstrom, 1993, 26), packed with shared meaning and normative direction, that can be called upon to legitimate a cause or ignite an emotional response. Thus the ecosystem health metaphor encapsulates both the ecosystem approach to human health and as well as some notion that an ecosystem, like an organism, can react negatively to some external stressor and become diseased or "unhealthy."
Another metaphor, introduced in the 1978 Great Lakes Bilateral Agreement, similarly attaches a human property by analogy to the ecosystem concept — the notion of *ecosystem* or *ecological integrity*. To combat the problem of

toxic contamination, a goal of this agreement was to "restore and maintain the chemical, physical and biological *integrity* of the Great Lakes Basin Ecosystem." Integrity, in its literal sense, can refer to soundness or wholeness of an entity or thing, as in removing a brick will threaten the structural integrity of a wall. Or integrity can refer to honesty, virtue, or honour as characteristics belonging to a human being.

Applied to ecology and ecosystems, the term becomes a hybrid of the two literal meanings. "Integrity," in the ecological sense, has come to be used to describe the optimal ecosystem state, slightly different from the notion of ecosystem health. While ecosystem health implies the ability of a natural system to operate under normal environmental conditions, ecosystem integrity implies that the system can maintain an optimal operating point while stressed *and* can continue evolving and developing through a process of self-organization (Kay 1993). Norton (1992) contends that "integrity" is a much stronger term than "health" in that it implies that ecosystems maintain their autonomous processes over time.

At the same time, the notion of ecosystem integrity is evocative of human values; that there is integrity or virtue in valuing a robust natural system. "Integrist interests" are those that hold that all natural phenomena likely play important and ultimately desirable roles but that *not* all our cultural phenomena are valuable in the long run. Accordingly, human culture must ultimately be adaptive to nature's evolving process, or that culture will not survive (Regier 1993). Those advocating integrity are remarkably similar to those in the North American ecological movement known as bioregionalism. Bioregionalists are committed to developing communities integrated with ecosystems and believe that human activities should be governed by the local biophysical environment. In this way, bioregionalism links political culture and the environment in a deterministic relationship. Frenkel (1994) makes the point that these ideas also appear similar to early 20th century environmental determinism, although he qualifies that bioregionalists stress egalitarian social objectives in their thinking about natural regions. Similar comments could be made of the ecological footprint idea (section III).

We caution that the uncritical application of the concepts of ecosystem health and/or integrity can lead to the application of "medical diagnoses" to achieve an agreed upon state of "health." The "new ecology" (a term applied to describe a major theoretical shift in the field of biological ecology) which calls attention to the instability, disequilibria, and chaotic fluctuations of environmental systems (see Zimmerman 1994) may in fact make the ecosystem health concept problematic in scientific application. Although it may resonate with environmental action and policy debate and formulation, both Sagoff (1985) and Schrader-Frechette and McCoy (1993) have drawn attention to uncertainty in ecological science. We assert that in addition to scientific ambiguities (e.g. no precise theories with predictive power, ambiguities associated with scale of analysis and rehabilitation, lack of agreement on key terms like community, stability) there are competing philosophical underpinnings (e.g. anthropocentric vs. biocentric outlooks) to the ecosystem health concept. But the metaphor remains powerful, resonating with meaning. We therefore advocate the cautious use of the term to mean the status of ecological systems in particular places at particular times and recognize it as much a mental construct as a "real state."

Measuring Ecosystem Health

For the moment, however, let us assume that human health is a relevant dimension of ecosystem health, although we will relax this assumption in later sections. For this discussion, we wish to examine generically measurement and the significance of definition (and metaphor) in measurement. This is especially important for something as complex and normative as ecosystem health. Measurement is "the procedure by which we obtain symbols that can be used to represent *the concept defined*" (Ackoff 1962, 177). It is "*rules* for assigning numbers to objects to represent quantities of attributes" (Nunnally 1967, 2). [Emphases have been added.] In fact, as Kaplan (1964, 167) observes "whether we can measure something depends, not on that thing, but on how we have conceptualized it, on our knowledge of it, above all on the skill and ingenuity which we can bring to bear on the process of measurement which our enquiry can put to use." Measuring ecosystem health thus depends on scientific ingenuity in the identification and selection of things to measure and on the bases (or ideas or models) for selecting the things that are worthy of measurement. Simply and crucially, measurement has to wait for the definition of what is to be quantified (Allen and Hoekstra, 1992). And literally, indicators indicate. What? They indicate progress towards some direction or goal stated in the model from which their importance is derived.

Definitions of indicators reflect the significance of their conceptual bases. Thus, Hunsaker and Carpenter (1990) define indicator as "a characteristic of the environment that, when measured, quantifies the magnitude of *stress*, habitat characteristics, degree of *exposure* to *a stressor*, or degree of ecological *response* to the exposure" (emphases added). Underpinning this approach to indicators are conceptualizations identified by the IJC (1991), namely self-maintenance or self-sustainability of ecological systems, sustained use of the ecosystem for economic or other social purposes and sustained development to ensure human welfare.

This conceptual underpinning of indicators may also be captured from a different literature, that attempting to measure human well-being. In this literature, (social) indicators are defined as "statistics which measure social conditions and changes therein over time for various segments of the population. By social conditions, we mean both the external (social and physical) and the internal (subjective and perceptual) contexts of human existence in a given society" (Land 1975, 14). Or a social indicator is:

> *a statistic of* ***direct normative*** *interest which facilitates concise, comprehensive and balanced* ***judgements*** *about the conditions of major aspects of society. It is in all cases a direct measure of welfare and is subject to the* ***interpretation*** *that, if it changes in the "right" direction, while other things remain equal, things have gotten* ***better*** *or people are "better off."* (U.S. Department of Health, Education and Welfare, 1969, 97 — emphases added).

Whichever definition we adopt indicators are firmly seen as being specified in a model of some aspect of environment or society which affects well-being or stress and demonstrates over time, patterns and variations in the issues of interest. Indicators are then goal-related. They are measures of "progress" and as essentially normative. There are also different types of indicators. For example, Rossi and Gilmartin (1980) identify six uses of social indicators:

- descriptive reporting of the state of society.
- analytic studies of social change, involving identifying why an indicator is trending in a particular way. For example, examining mortality rates by age, sex, occupation and region may point to important statistical relationships.
- forecasting the future, serving a predictive function, again requiring a model of part of the social system.
- evaluating social programmes — if programmes are effective (or ineffective) it should be possible to see their effects reflected in changes in appropriate indicator values. But it is extremely difficult to control for non-programme effects in real world situations, so it is difficult to gauge how much of the change in values is caused by the programme and how much by extraneous factors.
- setting goals and priorities, helping policy-makers come to better informed decisions. But indicators are only one element in setting goals and establishing priorities. Further once indicators become part of the policy-making process they become laden with normative judgements concerning the direction and magnitude of change, whether that means "better" or "worse" and whether the indicator is appropriate in particular circumstances. Indeed governments can alter the bases of indicators so that our picture of the world appears to change. Indicators of environmental contamination have been changed by several jurisdictions to ensure continued investment and job availability (Eyles 1994).
- developing a system of social accounts, so that all major aspects of well-being could be measured and integrated into a single social model as a system of social accounts (Gross 1966). But there is still no detailed and accepted theory that defines all variables and their interrelationships.

While we could insert "ecological" for "social" in this list, IJC (1991) identify five similar uses for environmental indicators:

- assessing the current condition of the environment in order to judge its adequacy (i.e. a compliance indicator)
- documenting trends in the condition over time, i.e. degradation or rehabilitation (a compliance indicator or sometimes an early warning indicator)
- anticipating hazardous conditions before adverse impact in order to prevent damage before the fact (i.e. an early warning indicator)
- identifying causative agents in order to specify appropriate management action (i.e. a diagnostic indicator)
- demonstrating interdependence between indicators to make the assessment process more cost-effective and to reinforce political will to make environmentally sound management decisions (i.e. correlations between various indicators. (IJC 1991, 13).

But goal or use — the purpose of the indicator, what it is meant to measure — is determined by the *a priori* model of how the world (society, environment or whatever) works. We must constantly be aware that indicators derive from models and depend on the nature of the models themselves.

Scientific models are utilized to accumulate and relate the knowledge we have about different aspects of reality. They are used to reveal reality and — more than this — to serve as instruments for explaining the past and present, and for predicting and controlling the future (Ackoff 1962).

There is not general agreement on defining models (see Harvey 1969). But there is appreciation for how they further scientific progress (see Giere 1991). Analogue models — casting the phenomenon of interest in terms of some other phenomenon (i.e. what it is like) — and iconic models — seeing that which is of interest in more abstract terms or at a different scale (i.e. what it is) are especially useful. Models thus help comprehend the world. All models are expressions of certain aspects of that for which they have been constructed (see Braithwaite 1962). It is more accurate then to speak of a model for something rather than of something, because the model is indeed intended for some conceptual purpose.

In this purpose the similarity between model and metaphor can be seen. Both are derived *a priori* from our understanding of the world. Both represent strongly held beliefs about how the world operates. Their difference lies in their testability in that a scientific model is meant to be testable and falsifiable whereas a metaphor is part of a world-view, challengeable only by revolutions in thought. Yet if we accept Allen and Hoekstra's (1992) view that observational techniques are filters then it is important to understand the "humanness" of models. Models have meaning only in the context of the "boundaries of science" and their meaning is dependent not just on their findings but on the form of the model itself: its scientific code. Thus as Bateson (1972) argues the structure of meaning is dependent on the code and how that is transformed into a message (scientific findings). If we share a code (a scientific model), we can understand missing parts — they are intelligible because we use the code to make sure all parts of the message fit. Ecosystem as abstracted system could operate in this way. Similarly Brown (1977) argues, models are derived from world-views and may take on metaphoric significance. This is especially the case when the relationship between science and its community life is close. We assert that this is the case with ecosystem health. And where the relationship is close, a particular way of practising science seems natural and right. (Normal) science becomes part of the (social) paradigm of a significant community.

In the above discussion, by linking model and metaphor, science and society, we have utilized ideas developed by Kuhn (1970) about the scientific framing of issues and scientific progress. These, to us, seem sensible. Ecosystem health is a paradigm — an intellectual perspective which defines the normal science within which a scientific community at a given time conceptualizes and researches its subject-matter.

A paradigm is a fundamental image of the subject-matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answers obtained. The paradigm is the broadest unit of consensus within a science and serves to differentiate one scientific community (or subcommunity) from another (Ritzer 1975, 7).

But what underlies this model of science for ecosystem health is a social paradigm which is a perceptual and cognitive orientation for interpreting and explaining aspects of the world. This underpinning reinforces the scientific approach and the normative commitment to a particular world-view, in this case the new ecological paradigm (see Olsen et al. 1992). This is well summarized by Cotgrove (1982, 88):

Paradigms are not only beliefs about what the world is like and guides to action: they also serve the function of legitimating or justifying courses of action. That is to say, they function as ideologies. Those who do not share the paradigm will question the justification for the action it supports. Hence, conflict over what constitutes the paradigm by which action should be guided or judged to be reasonable, is itself a part of the political process.

Science and politics cohere at the very root of what we measure, of the indicators we select and the models that frame our science. This is not wrong. But we must recognize the normative nature of indicators and models and we would argue that "metaphor" and "paradigm" allow this recognition. What we measure is only a selection out of all possible measurements, on the one hand scientifically and on the other conceptually, philosophically and politically. As we concluded in the introduction, ecosystem health is science in politics and hence science practised in a particular way for a particular purpose. Let us proceed and evaluate in the full knowledge of this.

III.

HUMAN ACTIVITY AND ECOSYSTEM HEALTH

Historical Perspectives

Our understanding of the impacts of human activity on environments has historically taken a number of forms. Critical to assessments of human environmental impact have been observations of components of ecosystems and interpretation of those observations within particular conceptual frameworks which ascribe causation of changes to natural, human and/or supernatural agency.

First Nations' peoples observed changes in wildlife populations and interpreted the role of their hunting activities relative to other possible explanations. Early historians have provided some of the earliest documentation of the changes which the Great Lakes region underwent with the arrival of Europeans. Clearing of forests, damming of rivers and streams, draining of wetlands and construction of cities led to major changes in historical basin ecosystems (Colborn et al. 1990). Although the present literature on such massive changes focuses on "development projects" in the hinterlands of Canada or the developing world, such extensive observable changes easily ascribable to direct human activity have been common in the basin's past and fundamentally transformed the ecosystems in which we now live and work.

Monitoring of commercial fish catches was a form of systematic observation of such changes introduced for economic reasons introduced in the last century (Hartman 1988). The dramatic changes in fish populations have been ascribed to a variety of human interventions within the basin, both intentional (e.g. fishing or stocking) and unintentional (sea lamprey movement through canals). Observation of basin ecosystems rooted in the biological tradition grew in the 19th century and moved to encompass the rich range of information on a wide variety of animal and plant species that we have available today. Increasingly, interpretation of the direct role of human harvesting became more difficult to discern from new "natural" cycles of resource availability or parallel habitat changes.

The 20th century has seen an increasing role for the physical and chemical sciences. Elucidation of temperature gradients and basic chemical parameters in water bodies was among the first descriptive work. For toxic substances in environmental media, methods have developed to quantify levels of gases, particulates and organic compounds in air (e.g. MOEE 1994a) and a wide range of both traditional inorganic (e.g. mercury) and organic compounds (e.g. combustion products) in soil and sediment. In water, sampling methods permit collection at distinct points within water columns of dissolved substances (e.g. phosphates), chemicals adsorbed to suspended particles (e.g. PAHs) and functional properties (e.g. biological oxygen demand).

Chemical analyses with increasing sensitivity have also enabled measurement of contaminants in many biological tissues of species which make up the food web (Environment Canada et al. 1991). Monitoring of organochlorine pesticides and their metabolites in the fat of fish and bird species along with human foods, fat samples and breast milk was initiated during the 1960s in response to both local use and aerial transport of DDT. Neurotoxic metals also became important: mercury because of the discovery of the role free-living bacteria play in transforming it to methyl mercury increasing its bioavailability and subsequent concentration up the food chain; and lead because of its widespread dissemination as a gasoline additive.

Together these data on media and species have permitted sophisticated modelling of contaminant sources and movements within the ecosystem (e.g. review by McKay 1992). For biological species and within a toxicological framework they provide the raw material for determination of exposure to toxic substances including calculations of dose based on the various routes of entry (McKone and Daniels, 1991). Yet, after some of the more dramatic cases of contamination were mitigated (e.g. phosphate loading), the task of ascription of causal relationships between ecosystem observations and past or present human activities has become increasingly challenging, both because of the complexity of ecosystem relationships and the political and economic implications involved.

Responses to Complexity

One response has been more intensive primary investigation on specific locales to better understand the relationships. Detailed documentation of a wide range of physical, chemical and biological processes in the Experimental Lakes area of north-western Ontario by limnologists (Schindler 1994) provided key information on the effects of acid precipitation. The researchers showed variation in the severity and rapidity of lake acidification among lakes according to geomorphic and biological characteristics, the resultant selection pressures on biological species such as plants and fish and the capacity for the partial reversal of effects with interventions to remediate acidification. Stage 1 assessments such as the Remedial Action Plan for Hamilton Harbour have pooled extensive information on Areas of Concern in the Great Lakes. For example, the report on environmental conditions and problem definition starts with basic information on geography, geology, current land and water uses, socioeconomic conditions and human health concerns. It goes on to examine in detail the physical processes which occur in the harbour, the quality of water and sediment and the status of a range of species which inhabit the harbour area. The report also includes the pollutant sources with a summary of loadings for specific compounds. Case studies of entire regions in distress have also been undertaken (Kasperson and Kasperson, 1994). These include heavily polluted parts of Eastern Europe, desert regions in Africa and other areas regarded generally as "ecological disasters."

Developing and linking models at different geographic scales has been a second response. One of the most advanced models using extensive data on contaminant loadings, sediment dynamics, water movements and other characteristics based on extensive sampling has been developed for Green Bay (Harris et al. 1994). Some Remedial Action Plans have expressed interest in use of geographical information systems (GIS) to manage the range of available data and examine linkages between monitoring and changes in the ecosystem (Louise Knox, Hamilton Harbour RAP, personal communication 1995). The feasibility of formulating watershed models in Areas of Concern, building on them to devise better documented lakewide models and finally linking these constituent models together to form an overall model of the Great Lakes basin was explored in an IJC sponsored workshop (Sonntag et al. n.d.). The prime purpose of models was to serve as a cross-disciplinary communication and learning tool for researchers, research managers, policy makers and the public. For this purpose, models were to reflect "the process required for integration of issues, information and actions which at some point includes the use of (technical) computer models." Models needed to "accommodate a range of scales from short-term and local to long-term and basinwide, ... represent ecological, economic and social issues, and ... capture the wide variety of feedbacks between sectors, time and distance in the system." A framework for linking across scales (basin, lake and watershed) was developed and modelling tools were suggested (system models, geographical information systems (GIS) and policy gaming). Policy gaming has been further developed by the University of Michigan to demonstrate the complex of ecosystem interactions and the role of human activity in every productive cycle (Underwood et al. 1994).

A third response has been the development of pro-active management approaches that implement policy decisions and then use the changes in ecosystem parameters to determine the role played by the changed factor in causing the original state (Hennessey 1994). Such an approach recognizes that evaluation of interventions (e.g. reductions in algal blooms with reductions in phosphorus loading) provides evidence of both causation by the inputs reduced and effectiveness of the change in human activities. Such an approach often involves natural scientists teaming up with social scientists to incorporate human impact on the environment into societal frameworks for the planning of human activities. It is assumed that human impacts will occur and the task is the assessment of impact across ecosystems and the prediction of impact across generations. A variety of management models have been employed. That adopted by OECD countries (1993) focuses on pressures being exerted on the environment (predominantly by humans), the state of the environment and responses of the environment to those pressures over time. Wackernagel and colleagues (1993) have set out methods of calculating the "ecological footprint" of human activities on the environment based on provision of resources in renewable ways. They reason that:

> *every category of consumption or waste discharge requires the productive or absorptive capacity of a finite area of land or water (ecosystems). Adding up the land requirement of all these categories gives us an aggregate or total area which we call the "ecological footprint" of the economy on the Earth.*

Such an approach aims to achieve neutral impacts of human activity on environments. Planners are developing ways of assessing modified and built environments to recognize the interdependence of human activities and ecological processes within watersheds and other such natural geographic boundaries (Royal Commission on the Future of the Toronto Waterfront 1992). Such frameworks point out the increasing inseparability of human activities from environmental processes and the increasingly positive role that changes in human activities could play in reducing impacts on the environment. Reductions in phosphorus loading to the Great Lakes, particularly Lake Erie, resulting in decreased eutrophication, provide an important example of the positive role human decisions and resultant activities have played (Phosphorus Management Strategies Task Force 1980).

Role of Human Innovation and Adaptability

Is the significant role of human innovation and adaptability fully recognized? Much of the earlier literature emphasized exploiting and harnessing nature (e.g. Kahn 1971), while at the same time recognizing that human betterment is predicated on a changing relationship with the environment (Wilkinson 1973). The increasing impact of humankind on the natural environment cannot be doubted (see Goudie 1994). But nor should be the power of human invention and innovation. It is not our intention to review this literature in depth but some cultures are more innovative than others (Rogers 1962). This suggests that culture and social organization mediate between ourselves and our uses of and activities in the ecosystem. Any activity will affect the ecosystem in some way. But does innovation necessarily impact negatively on the environment? Survival in environments with low biological productivity demands innovation and social organization. The Inuit seasonably exploit the tundra through innovative social relationships — flexible alliance systems (Spencer 1959). In studying the effect of human activity on ecosystems, we must, therefore, not only examine the ecosystem but human adaptability, as constructed in culture as well. A focus of ecological anthropology (e.g. Geertz 1963; Vayda and Rappaport, 1976) is based on Steward's (1955; 1978) ideas on the causal connections between social structure and way of life. The nature and rate of environmental change (often degradation) cannot be divorced from this way of life, including needs, wants, technology and values. Why does human activity in an environment take the form it does? This, we argue, is a vital question for advocating particular changes in activity for ecosystem "protection." Further, the form of activity is predicated on how a people perceives resources and its relationship to the environment. It is worth recalling that there are several ways to perceive that relationship. Kluckhohn (1953) suggests three:

- people as subjugated to nature, living at the mercy of a powerful and dominant environment;
- people as over nature, dominating, exploiting and controlling the environment; and
- people as an inherent part of nature, trying to live in harmony with nature.

These relationships are encapsulated in dominant social paradigms (section II). At the present time in the Great Lakes area, there seems to be tension between the second and third, although it may be easier to understand the present status of the debate over ecosystem by asserting that the tension is exacerbated by the fear of the first, especially with respect to human health and well-being if control over our affairs is apparently reduced to the demands of ecosystem health.

These concerns are often now considered when credible scenarios of potential outcomes are expressed using a range of tools. Ecological risk assessment and the more legally bound, environmental impact assessment, are increasingly being carried out on a wide range of human development projects and interventions. These tools permit explicit examination of trade-offs between human oriented outcomes and environmental impact and innovative ways to reconcile them. Although often cast in traditional cost-benefit terms with the cost of mitigation procedures being weighed against the benefits of the particular development, other approaches to incorporating human interests and values in ecosystems are increasingly being advocated (e.g. human health by Public Health Coalition 1992). Ecological economics is one emerging field that questions the usual micro-economics approaches to valuations in development (Constanza et al. 1991). Among its practitioners, Daly (1991) has argued for the need to estimate and set limits on the maximum scale of human development activities possible within particular ecosystems up to the global scale.

Ecosystem as a Core Value

So how much is the ecosystem valued? Human valuation of environment and ecosystems must necessarily consider a range of social interests relating to how human activity is perceived in conjunction with the ecosystem. Which interest-groups in particular pursue ecosystem as an important life-domain? Environmentalism — valuing the environment in its own right — became an important value among the public in the mid to late 1980s in Canada. Using Gallup Canada polls, Bakvis and Nevitte (1992) note its rise from nowhere to great significance in 1988 and 1989, such that over two-thirds of polled Canadians were very concerned about pollution, this rising to over three-quarters in 1990. At that time (1989), nearly one-fifth of Canadians rated the environment as their top concern (Maclean's, January 1995). Evidence from the national election campaign of 1988 shows protecting the environment was seen as more important than creating jobs by both genders, all age groups, levels of educational attainment, all income groups, all occupational groups, all regions and both official language groups. It was skewed towards the higher status groups (Bakvis and Nevitte, 1992). To understand these value-positions, consideration of economic and political context is important. These polls were taken at the end of the long boom in the 1980s (1982-9) and before the bite of the early 1990s recession. Let us note that in 1994, only one percent of Canadians viewed the environment as their top concern (Maclean's, January 1995). Environment was also behind six other priorities (education, debt and deficit, child poverty, unemployment, job creation and crime and justice) for federal government action (A6, Globe and Mail, February 25, 1995).

If values are important in understanding how the impact of human activity on the environment is seen, it is perhaps more important to examine environment as a value in relation to other values and important life-domains. Environment tends not to be valued highly in relation to other domains. It is those domains that directly indicate (health) or help establish our well-being (family, income, standard of living) that are most highly valued (Eyles 1985, 1990). In one investigation in which people were asked the defining characteristics of where they lived, environment trailed such dimensions as social relationships, economic well-being, memories, roots and even no opinion and nothing (Eyles 1985).

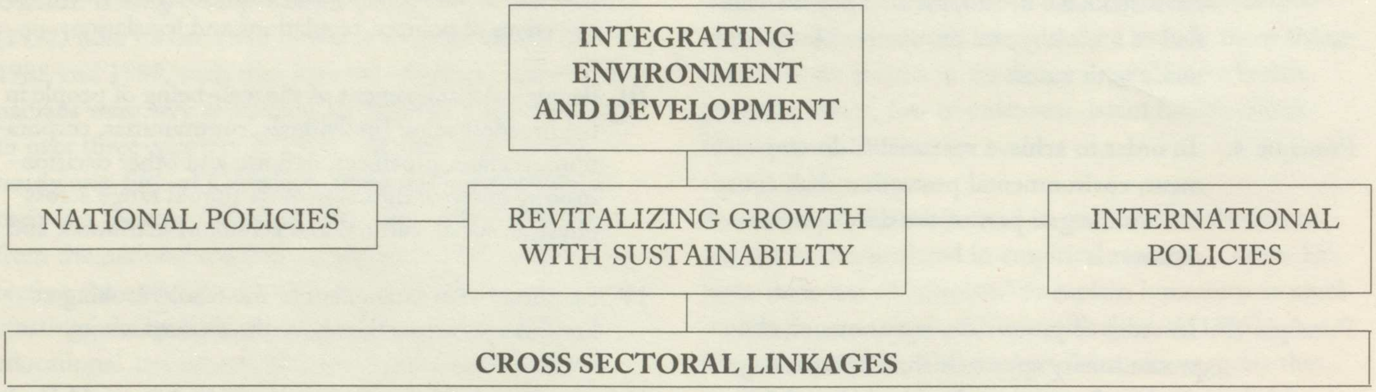
Environment or ecosystem does not then necessarily engage significant life-domains or core-values. The issue can, however, be looked at differently. When does environment engage us? And what values are expressed? Our answers can only be suggestive. First, we are engaged when we are threatened. Edelstein (1988) in his work on contaminated communities (and Legler, New Jersey, in particular) makes the useful distinction between lifestyle and lifescape, the former referring to people's way of living, the latter to our fundamental understandings about what to expect from the world around us — our social paradigm. When lifescape is threatened, core-values are threatened. These ideas have not been fully developed although some research suggests they include those things that indicate threats to the future — children's health, property values, fear of unknown, latent health effects (Eyles et al. 1993).

Second, the values expressed in environmental concern are not well-articulated in empirical research. There has been some use of "altruism" to explain intentions to ameliorate environmental problems (Black et al. 1985). As Stern et al. (1993, 324) explain, "altruism suggests that pro-environmental behaviour becomes more probable when an individual is aware of harmful consequences to others from a state of the environment and when that person ascribes responsibility to her/himself for changing the offending environmental condition." This is but one value-orientation. Others include "the land ethic," which emphasizes the welfare of non-human species (Heberlein 1972) or of the biosphere itself, as in deep ecology (Devall and Sessions, 1985). Still others implicate economic and socio-biological orientations (Hardin 1968; Olson 1965). Altruism seems the most likely value-basis for environmental concern. Through it, concerns for the ecosystem are linked to concerns for other humans. Implicated in it are other fundamental human values such as community, equity and justice. Thus ecosystem health is indirectly pursued through human actions directed at humankind. But let us be clear this emphasis on ecosystem health through altruism is but one value-orientation and it is a fragile commitment. Bluntly, human activity is geared toward human betterment and human health and well-being. We recommend that research on the relative importance of core values among Great Lakes populations be undertaken to clarify some of these issues.

Visions of Ecosystems

But in order for a particular set of ecosystem health values to be pursued, visions and objectives such as development, growth, progress and sustainability must be defined and then operationalized (the options, mechanisms and strategies). Agenda 21 from the Rio Conference is one of the most comprehensive policy documents to describe these various terms, disaggregate them into linked components and suggest strategies for achieving sustainable development (UNCED 1992). Among the 27 principles three are of particular importance to the present discussion:

Figure III. Revitalizing Growth with Sustainability



COMBATTING POVERTY	Providing sustainable livelihoods (Chapter 2.1)
CHANGING CONSUMPTION PATTERNS	Less wasteful lifestyles: Sustainable consumption levels, informed customer choices (Chapter 2.3)
DEMOGRAPHIC DYNAMICS AND SUSTAINABILITY	Global challenges, national and local level integration of population and environment (Chapter 2.3)
HEALTH	Pollution health risks: urban health, basic needs, communicable diseases, vulnerable groups (Chapter 2.4)
HUMAN SETTLEMENTS	Shelter, land and settlement management, environmental infrastructure, energy and transport, human resources and capacity building, disaster-prone areas (Chapter 3.1)
URBAN WATER SUPPLIES	Drinking water, sanitation, intersectoral planning, monitoring (Chapter 3.2)
SOLID WASTE MANAGEMENT	Waste minimization, safe disposal, expansion of services, recycling (Chapter 3.3)
URBAN POLLUTION & HEALTH	Air pollution, municipal health planning, radiation protection (Chapter 3.4)
LAND RESOURCES	Integrated assessment, development and management, protection of quality and resource, drinking water, sanitation, water for agriculture (Chapter 4.2)
ENERGY	Sustainable energy development and consumption, household, transport, industry (Chapter 4.3)
SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT	Policy, planning and programming, human resources participation, land use, conservation and rehabili tation, fresh water, plant and animal genetic resources, pest management, plant nutrition, rural energy, rural employment, food security (Chapter 4.4)
SUSTAINABLE FOREST DEVELOPMENT	Multiple utilization of trees, forest and lands; assessment and monitoring, international and regional cooperation (Chapter 4.5)
MANAGING FRAGILE ECOSYSTEMS	4.6.1 Combating desertification and drought. Information and monitoring, afforestation and reforesta tion, alternative livelihoods, anti-desertification programs and action plans, drought preparedness and relief. 4.6.2 Sustainable mountain development. Information, integrated watershed development alterative livelihoods information, integrated watershed development, alternative livelihoods
ECOLOGICAL DIVERSITY	Information, benefits and use, conservation, capacity building (Chapter 4.7)
ENVIRONMENTALLY SOUND MANAGEMENT OF BIOTECHNOLOGY	Productivity of food and feed, health, environment protection, safety enabling mechanisms, interna- tional cooperation (Chapter 4.8)
ATMOSPHERE	Sustainable energy development and consumption, transport systems, industry, agriculture, ozone depletion, addressing uncertainties (Chapter 5.1)
OCEANS AND SEAS	Coastal area development, marine protection, living resources, uncertainties and climate change, international cooperation and coordination, island development (Chapter 5.2)
TOXIC CHEMICALS	Chemical risks assessment, classification and labelling, information, risks management programs (Chapter 6.1)
HAZARDOUS WASTE	Cleaner production, waste minimization, institutional capacities, international cooperation for transboundary movement (Chapter 6.2)
RADIOACTIVE WASTE	International agreements for safe management (Chapter 6.3)
EDUCATION, PUBLIC AWARENESS AND TRAINING	(Chapter 7.1)
STRENGTHENING THE ROLE OF MAJOR GROUPS	Women, youth, indigenous people and their communities, NGOs, farmers, local authorities, trade unions, business and industry, scientific and technological community (Chapter 7.2)

Source: UNCED (1992)

IV.

HUMAN HEALTH IN ECOSYSTEM HEALTH

Why Human Health?

"To the great majority of people, the protection of human health is the most important goal of environmental management" (IJC 1991, 29).

In our discussion of ecosystem health, we saw one of the main reasons why human health has to be seen in relation to ecosystem health. The use of ecosystem health as a metaphor has resulted in the inclusion of human health in ecosystem health discourse. Human health is simply in there. Distress in the ecosystem is, therefore, believed to have negative consequences for human health. Ecosystem health is thus a root metaphor — it contains within it ultimate presuppositions or frames of reference for discourse (and action) in the world (see Brown 1977). It becomes a "normal" way of seeing the world (see Kuhn 1970) and our language tells us what to see and what we do see.

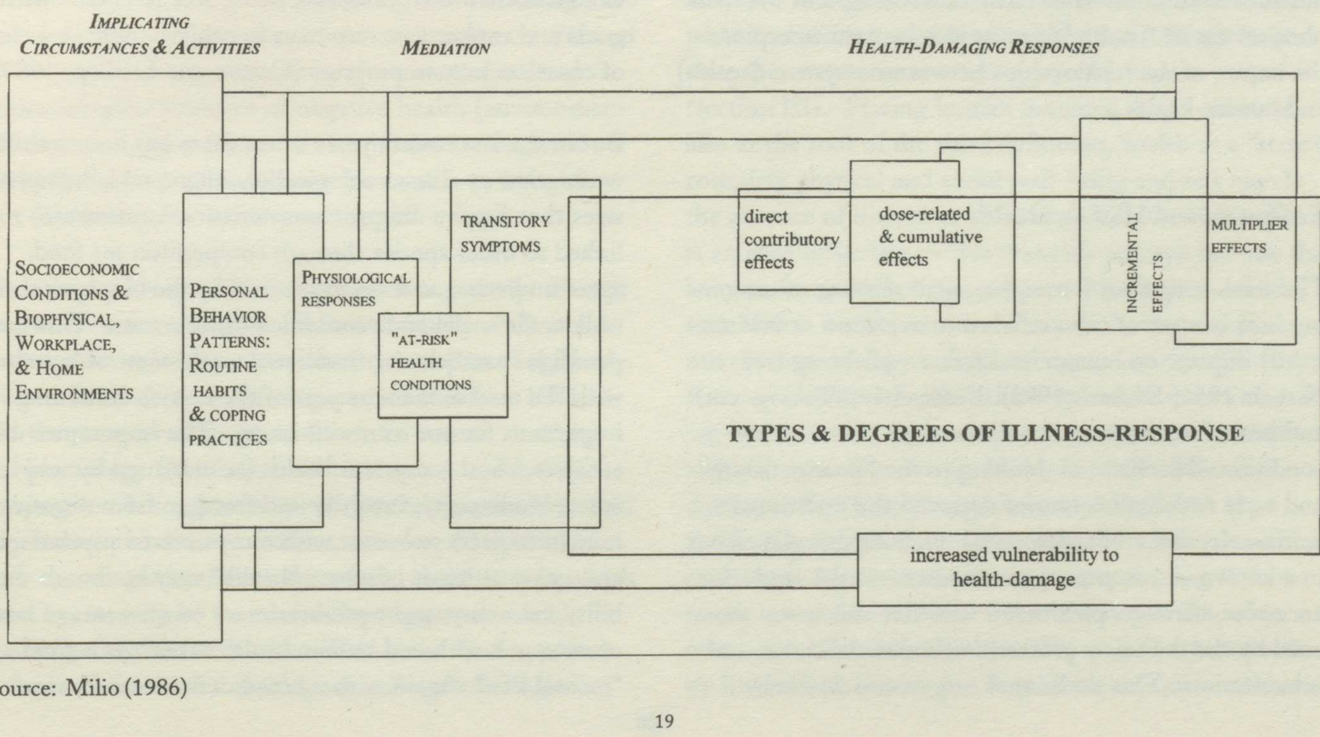
A similar use of language in which there resides a root metaphor is "healthy" cities, communities or environments, all of which are part of "healthy" public policy. One of the leading proponents of such policy, Milio (1986) argues:

Typical personal behaviour among Americans, even as variations occur, is closely linked to a growth-orientated, industrial economy. It is a reflection at the personal level of directions taken on the national scale. The lavish use of energy for production brings more sedentary jobs and modes of transportation which reduce physical exercise and caloric expenditure. In order to obtain and retain what this affluent society makes available only to some, Americans have embraced a system of competition which requires time-orientated activity, calculation and fast pace which in turn contribute to accidents and generate distress. The ensuing desire to seek relief quickly makes for greater use of readily available "solutions" such as cigarettes, alcohol and tranquilizers.

Production for commercial consumption, valuing saleability first inevitably contributes to a reduction in the quality and safety of ambient air and water, of workplaces and of foods and other goods.

At the same time that economic fluctuations change personal economic resources and modify consumption

Figure IV. Mutual-Causal Interconnections in Contemporary Health and Illness



Source: Milio (1986)

patterns, the web of social ties is itself changed. This stems from economy-based distress in families, resulting in more separations and divorce and from intensity of work, loss of job security, consequent worker alienation, and diminishing labour organisational ties. All affect the pervasiveness of distress and the capacity of large proportions of the population to use effective coping patterns (see Figure IV).

This is all seen as a "public health" issue in which in the word "health" lie also income security, psychological well-being, social support, caring environments and so on. The strength of this argument is intensified by some advocates of healthy public policy or the new public health suggesting that there is no need to define health as it is a de-energizing task leading to inaction (Ashton and Seymour, 1988). Pederson et al. (1988) have explored the conceptual and research bases for healthy public policy approaches, noting its predominantly exhortatory nature growing out of public health paradigms. They remarked that it was more a shared ideology than a theoretically grounded approach to what is fundamentally a social process. The metaphor — healthy community — becomes the model which shapes the practice of science and the demands for action. So too with ecosystem health. The same danger is present. The metaphorical use of "health" which encompasses so much of what we feel about ourselves in the world suggests we are the community, we are the ecosystem, our health is its health. But we cannot not assume such a congruence between human health and ecosystem health. While at one level, human health is added to ecosystem because of the metaphorical use of "health," it must also be used to explore the nature of the relationships between ecosystem (health) and human health.

Ecosystem and Human Health

There is a long tradition in the social sciences of examining how ecosystem (also referred to as nature or environment) impacts on human health and well-being (see Nisbett 1966; Dickens 1992). Environment (ecosystem) and health are fundamental dimensions of the human condition. Much social thinking in the late nineteenth and early twentieth centuries regarded the traditional community order of stable social relationships played out in a known and respected environment — the land of ancestors, heritage, plenitude — as that which was threatened by the then new processes of industrialization and urbanization. This traditional — gemeinschaftlich (Tonnies 1955) — way of life — small-scale, rural, in tune with nature and environment — still has great resonance. Indeed many of the great social thinkers — Durkheim, Tonnies, Maine, Marx — have passed down to us, unwittingly, an anti-urban, anti-industrial set of attitudes or, to put it more strongly, world-view (Glass 1968). The new urban and industrial world, on the other hand, was dominated by individualized, impersonal and shallow relationships forged by calculation and manipulation. Modernity then results in a slow and steady alienation:

With each crossing of the street, with the tempo and multiplicity of economic, occupational and social life, the city sets up a deep contrast with small town and rural life with reference to the sensory foundations of psychic life. The metropolis exacts from men as a discriminatory creature a different amount of consciousness than does rural life. Here the rhythm of life and sensory mental imagery flow more slowly, more habitually and more evenly (Simmel 1950, 39).

This alienation is not only from others but also from our surroundings — our habitat. Indeed, Marx (1975) would argue that this alienation is deep-seated. As part of nature, our alienation from that also alienates us from ourselves (our species-being). This alienation becomes complete with the "success" of industrialization so much so that our dominant world-view could be described as human exemptionism with people being seen as distinct from and dominant over all other species. People are in charge of their own destinies, being able to choose their goals and exploit vast resources to achieve them in a chain of ceaseless human progress (Catton and Dunlap, 1980).

But in the last twenty years or so, there has been a shift in world-view to a new ecological paradigm, which emphasizes that despite unique characteristics, humans are linked to other species through competition for food, space and water and are influenced by the biophysical as well as the social and economic environments. This new paradigm parallels our traditional world-view of harmony with the environment as part of the human condition, important for our own well-being. The importance of ecosystem and ecosystem health (as measured by resilience, biodiversity, integrity and freedom from negative human impact) resonates with our perceived psychological and spiritual needs of where "health" may be found. Stability, harmony, and equilibrium are constituents of both ecosystem health and human health as seen as a good "mental life." Again with a broad definition of human health, it and ecosystem health are entwined. What happens if we narrow the focus in terms of defining human health?

Defining Human Health

> *There are many words that we think we understand until we begin to question what they mean. "Health" is one of them. At first sight, the word looks quite straightforward. It identifies a state of being to which most of us aspire — a "blessing," a desirable quality, but one which we are often told money cannot buy. But if we pause for a moment to think just what health is, the picture becomes more complicated.* (Aggleton 1988, 1).

In his own review, Aggleton uses two dichotomies to summarize research on definitions of human health, that between official (i.e. views of doctors and other health professionals) and lay (those of non-professionals derived from their own experience) and within the official between negative (the absence of qualities) and positive (the presence of qualities). We shall not review lay definitions, despite their importance in orienting people's behaviour to health care, lifestyle options and the environment (see Herzlich 1983; Eyles and Donovan, 1990; Litva and Eyles, 1994). We shall, however, briefly review both types of official definition, noting that negative ones emphasize the control of identified conditions and positive ones the promotion of identified conditions. We shall then go on to explore in the following two subsections the human health consequences of the environment as framed by these definitions, respectively the toxicological and epidemiological evidence of negative health (environmental burden of illness impacts) and the determinants of health framework of which environment is an integral part (environmental conditions for well-being).

There are two ways of defining health negatively. First it may be seen as an absence of disease usually understood as the presence of some abnormality in a part of the body. Despite difficulties in defining normal (Mishler 1981) and the presence of great variations in human anatomy and physiology (Macintyre 1986), this is a widely held perspective. It suggests a search for the abnormalities and their associated diseases (cancer, measles, dermatitis), their causal agents, the environmental conditions in which these agents may be found and the triggers that lead to their affecting human health. This biomedical approach is the basis for most toxicological and epidemiological research on human health consequences, on exposure and outcomes, and is used analogously in ecosystem health research in terms of absence of distress. We will not replay here the strengths and problems of metaphor and analogue. But let us note that disease is measured by cause-specific mortality, morbidity and activity limitation (see section V).

Secondly, health may be seen as the absence of illness. Illness may or may not accompany disease. Thus a distinction often used is that disease is diagnosed by a physician or other health care professional, while illness is experienced. So if an individual does not experience anxiety, pain or distress, he/she is healthy. Health in such terms is relativistic but it points to the importance of feelings for well-being. It is often measured in terms of self-reported health status or health satisfaction (see section V). Overall, though, negative definitions of health lead to considering the environmental burden of illness and evidence for such a burden.

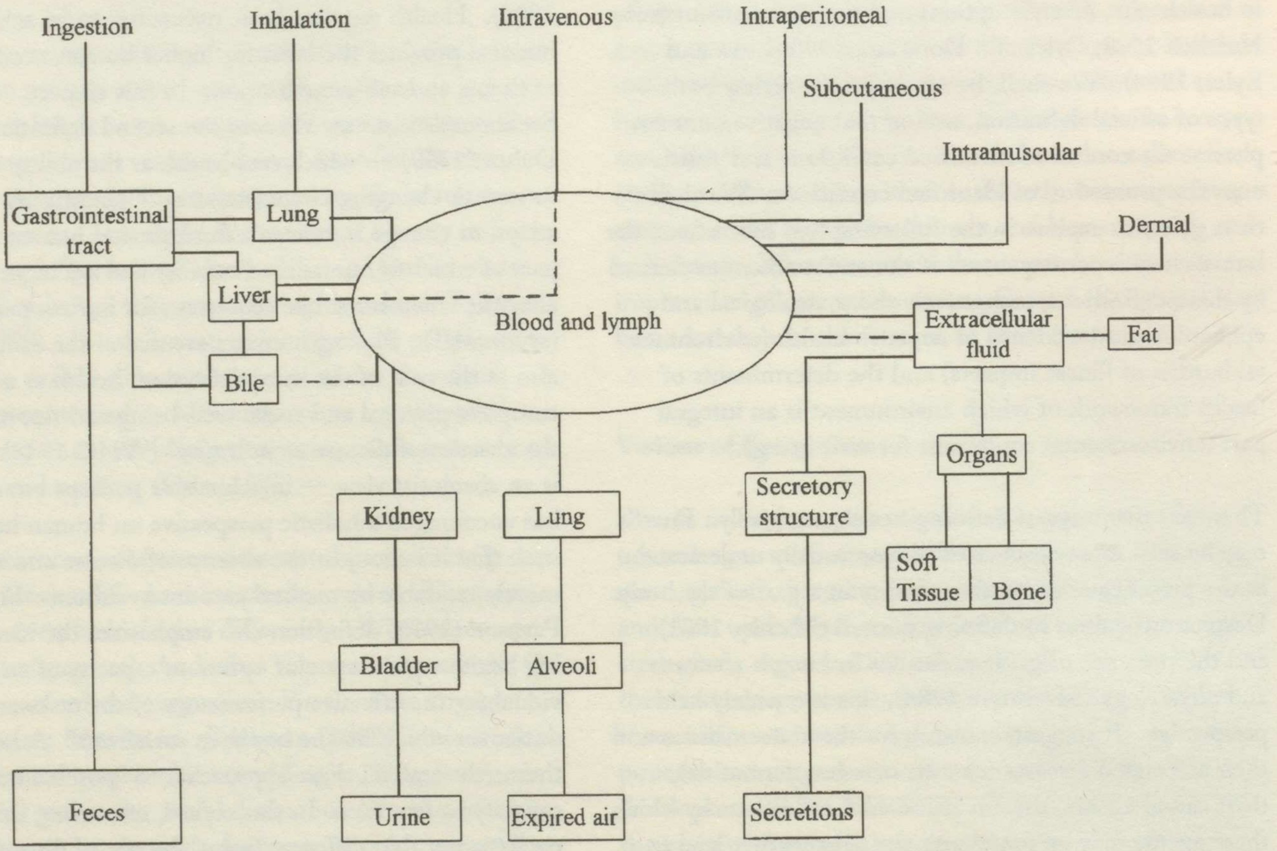
In contrast, there are four positive definitions of human health, although all cohere around one or two themes. First, health may be seen as that which enables people to achieve their maximum personal potential (Seedhouse 1986). Health requires basic necessities to be achieved but also provides the basis for higher human needs, such as caring and self-actualization. In this respect, Seedhouse's ideas are close to the second definition — Dubos (1959) — which sees health as the ability to adapt to new or changing circumstances. This capacity to adapt, to change is seen as a fundamental human trait, part of which is humankind's ability and willingness to alter the environment or ecosystem for human purposes (section III). Placing human potential at the centre is also at the root of the third definition, health as a "state of complete physical and social well-being and not merely the absence of disease or infirmity" (WHO 1948). This is an absolutist view — unachievable perhaps but one that has encouraged a holistic perspective on human health such that it is not just the absence of disease and is not merely treatable by medical care interventions. Finally, Parsons' (1972) definition also emphasizes the ideal, seeing health as "the state of optimum capacity of an individual for the effective performance of the tasks and duties for which he/she has been socialized." A key theme through all these approaches to "positive health" is capacity to function. In this regard, measuring this capacity is not that different from "absence of illness" in terms of self-reported health status or indicators of activity limitation. It may also be possible to measure this capacity indirectly by days off work through illness and visits to family practitioners and broadly in terms of general quality of life indicators (section V). Overall, whereas negative definitions lead to an evaluation of burdens of illness, these positive ones lead to evaluating well-being and the environmental conditions which sustain it.

Environmental Burden of Illness

McMichael (1994, 14) argues that "estimating the health risks attributable to specific exposures in the occupational environment or to definable personal behaviours... is relatively straightforward. It is much less easy to make quantitative estimates of the impact of environmental pollution and degradation." In some respects, the problem is twofold. First, it is necessary to get a handle on the effects of pollutants or contaminants on health. Second, how do those effects relate to, interact with other burdens of illness so we may comment on the contribution of environment to ill health? We deal with the second, conceptually at least, in the next section on environmental conditions for well-being.

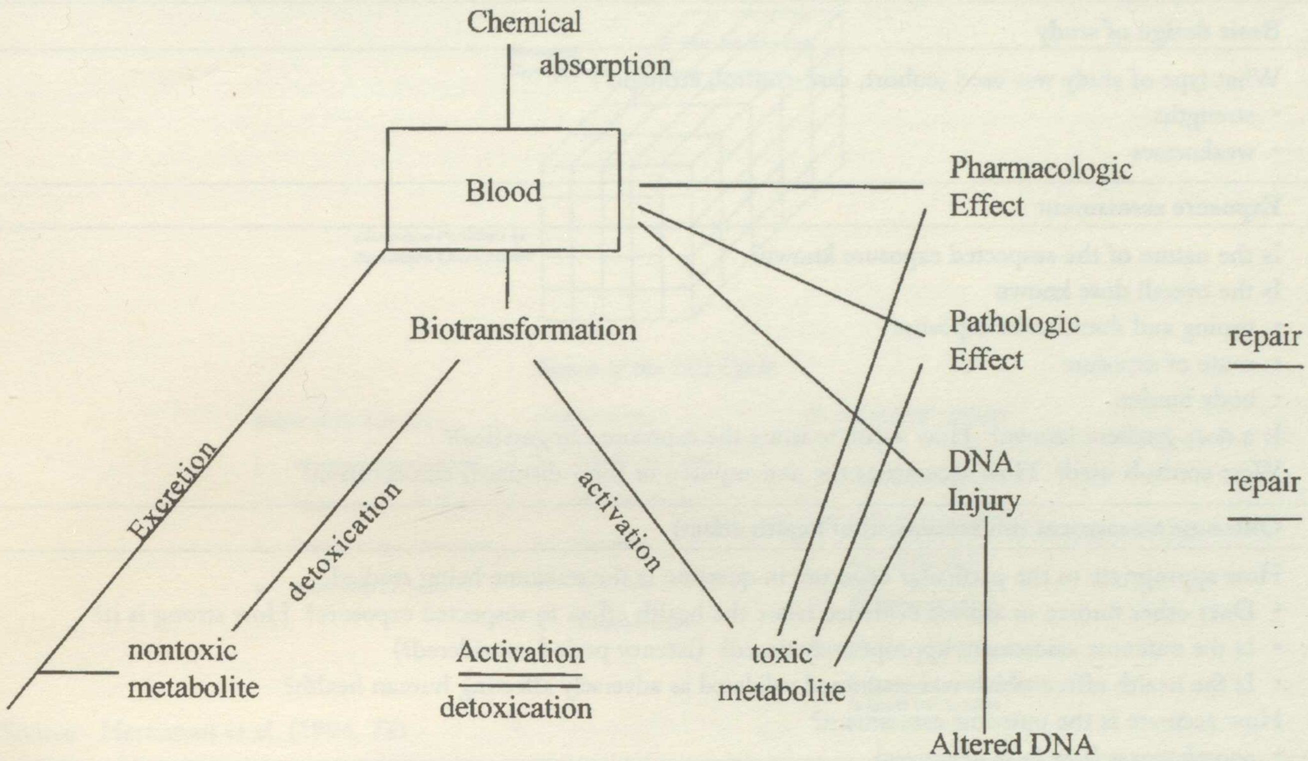
Turning to what appears to be the simpler task, we see that it is fraught with difficulties. Most diseases are caused by multiple factors while a specific environmental exposure may have many different health effects which may in turn have different latency periods. The toxicity of chemicals, solvents and microorganisms is dependent upon how they reach the body, get excreted, accumulate or undergo transformation over varying time courses. Figures V and VI illustrate the complex nature of these processes. How then might the specific toxicological outcome to a particular chemical exposure at some earlier point in an individual's or their parents' lives be related first to health and environment and secondly to a contribution to the environmental burden of illness? Health disorders vary in severity and while it is relatively easy to document the most severe (mortality, activity limitation) the less severe may be missed (poor sleep patterns, sensory deprivation). General morbidity is notoriously difficult to attribute to definable physical, chemical or biological exposures partly because of gaps in exposure data.

Figure V. Routes of Adsorption, Distribution and Excretion of Toxicants in the Body.



Source: Klaassen (1986, 30)

Figure VI. Schematic Representation of the Disposition and Toxic Effects Produced by Chemicals



Source: Klaassen (1986)

It is important that we proceed with caution, and that studies of environmental health effects be critically appraised. Table III is one such way of appraising epidemiological studies (Frank et al. 1988). Such studies are limited by the difficulties in assessing the exposures to toxic agents at environmental exposure levels (i.e. accurately classifying who is relatively highly exposed and who is not). All epidemiological studies examine the difference in health outcomes between those who are more highly exposed and those who have lower exposures to the agent of concern. If a gradient of exposure cannot be found, epidemiological methods are useless, even though the consequences of the exposure may be very real and very severe. Consider the difficulty in knowing whether smoking was related to lung cancer if everyone smoked 20 cigarettes a day. Even if there is a gradient of exposure, we have to be able to correctly classify those who are highly exposed and those with low exposure and to get some reasonable measure of the exposures. Otherwise the misclassification of exposure will lead to false negative results in studies. It is quite possible that some pollutants that are widely dispersed in the environment are having effects we cannot detect epidemiologically for precisely these reasons. Epidemiological studies also require that the outcome — the health effect — be measured accurately. There are many issues in the definition and accuracy of human health records that cannot be discussed here.

However much of the concern over environmental exposures is related to subtle effects — influences on neurobehavioural development, IQ, psychosexual development and fertility that may be significant if they occur broadly throughout the whole population, although the impact or deficit for an individual is of little consequence. Other outcomes are of high significance for the individual — cancers, birth defects — but are of low probability at environmental levels of exposure. Because these outcomes can be caused by many factors it is often difficult to determine if an environmental factor is adding to the burden of disease or illness. As well, overlapping exposures all of which in themselves may increase the risk of a particular symptom can together seem to account for more than 100 percent of increases in symptoms. Appropriate statistical techniques must be used to deal with this problem by adjusting for the lack of independence between exposures and interactions between exposures and personal characteristics (see Walter 1983).

Hertzman et al. (1994) emphasize the importance of partitioning the population in ways that consistently

Table III. Criteria for the Evaluation of Epidemiological Studies Linking Environmental Toxic Exposures and Health Effects

1. Basic design of study

a. What type of study was used (cohort, case-control, ecologic?)
- strengths
- weaknesses

2. Exposure assessment

a. Is the nature of the suspected exposure known?
b. Is the overall dose known
- timing and duration of exposure
- route of exposure
- body burden

c. Is a dose gradient known? How accurate is/are the exposure category(ies)?
d. Were controls used? How accurate is the non-exposed or (non-diseased) classification?

3. Outcome assessment (measurement of health effect)

a. How appropriate to the particular exposure in question is the outcome being studied?
- Does other human or animal evidence relate the health effect to suspected exposure? How strong is it?
- Is the outcome assessment appropriately timed? (latency period considered?)
- Is the health effect which was examined validated as adversely affecting human health?

b. How accurate is the outcome assessment?
- completeness (few false negatives)
- correctness (few false positives)

c. Is there possible bias in the ascertainment of the health outcome for the various exposure category(ies) and controls?

4. Control for other factors influencing outcome

a. Are the exposed category(ies) — or cases, in a case-control study — and controls comparable (except for exposure)?
- nature of underlying populations
- sampling bias

b. How great is the problem of confounders likely to be?
- specificity of health outcome studies for the particular exposure

c. How successfully were possible confounders controlled for?
- adequacy of matching or adjustment for all possible confounders (age, sex, socioeconomic status, ethnicity, other exposures to toxicants, access to medical care, secular time trends)

5. Strength of association between exposure and outcome (relative risk)

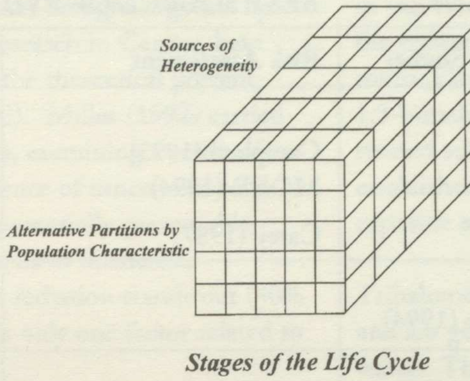
a. Does the relative risk have clinical or practical significance?
b. Does the relative risk have statistical significance?
c. Was a clearcut dose-response gradient demonstrated?
d. If no statistically significant relative risk exposure was found, was the statistical power of the study adequate to find a risk or practical importance if it existed?

6. Evaluation of final conclusion

a. If the result is positive, could it be a false positive association?
b. If the result is negative, could it be a false negative association?
c. Is the result consistent with other well-conducted studies of the same association and/or related epidemiological knowledge on the distribution and dynamics of the health outcome or condition in question?

Source: Frank et al. (1988, 138)

Figure VII. Model for Investigation of Heterogeneities in Population Health Status



Stages of the Life Cycle	*Characteristics*	*Source of Heterogeneity*
1. Perinatal: preterm to 1 year	1. Socioeconomic status	1. Reverse causality
2. Misadventure: 1-44 years	2. Ethnicity/migration	2. Differential susceptibility
3. Chronic disease: 45-74 years	3. Geographic	3. Individual life-style
4. Senescence: 75+ years	4. Male/female	4. Physical environment
	5. Special populations	5. Social environment
		6. Differential access to/response to health care services

Source: Hertzman et al. (1994, 73)

define subgroups differing greatly and systematically in their health status. Figure VII shows how the three elements of their conceptual framework — stages of the life cycle, subpopulation partitions and sources of heterogeneity in health status at the aggregate level — mesh together. They advocate longitudinal studies as an important research strategy. But let us note that "exposure" is dealt with implicitly as one element of population characteristics and as a source of heterogeneity. Yet human populations are themselves changing, increasing their heterogeneity and the likelihood of susceptibility in subgroups . We therefore recommend that "exposure" itself constitute a key element. Much work has already been carried out on sources of exposure through various media — water, air, soil, food, — and pathways for exposure to affect human health as will be reported here.

Environmental health risks can be estimated by risk assessment protocols built on such exposure data and on animal data linking exposure to such health effects as cancer and birth defect risks. In some situations health effects that have manifested themselves in occupational settings can reasonably be extrapolated back to environmental exposures. More importantly occupational epidemiology often confirms that health outcomes seen in animals will occur in humans if exposure is high enough (e.g. Friberg 1984).

What despite these uncertainties and caveats do we know? In answering, we will limit the discussion to the health impacts that may be occurring in human populations living in the Great Lakes basin as a result of exposures in the ambient environment (exposure to outdoor air, drinking water, recreational water use, exposures to soil) or mediated by the ambient environment (exposure through food). We have included those toxic substances in this section for which there is good epidemiological evidence or good estimates based on risk assessments or expert reviews. This discussion is not an exhaustive review of the evidence of exposure-health outcomes relationships for any of the health effects considered. It is meant to cover briefly those areas in which further research and prudent action are worthwhile. Table IV lists the toxic agents of most concern in the Great Lakes basin and the research literature that describes their health impacts. Studies from the Great Lakes area are noted if these exist.

Starting with cancers, a considerable body of toxicological and epidemiological data has developed because of the stakes involved for either the producers of chemicals or those exposed to chemicals, particularly in occupational settings. Higginson (1992) reviewed some of the studies attributing portions of the cancer burden to different factors and pointed out the gaps on exposure information. To produce estimates of burden of illness from cancer,

Table IV. Nature of Evidence on Toxic Agents of Concern in the Great Lakes Basin

TOXIC AGENTS	BEST SOURCE OF EVIDENCE		
	Epidemiological Studies	Risk Assessment	Other
Combustion products: • **1,3-butadiene** • **diesel fumes**		Campbell (1993) MOEE (1994) Carey (1987)	
Dusts/Particles:	Schwartz (1991) Dockery & Pope (1994)		
Gases: • **ground level ozone & SOx**	Burnett et al. (1994)		Pengelly et al. (1994)
Infectious: • **bacteria, viruses** • **parasites such as cryptosporidium**	Seyfried et al. (1985 I & II) MacKenzie et al. (1994)		
Metals: • **aluminum** • **cadmium** • **chromium VI**		Friberg (1984) Archibald & Kosatsky (1991) Campbell (1993), MOEE (1994)	Nieboer et al. (1995)
• **lead**	Needleman& Bellinger (1991)		
• **mercury**	Langlois et al. (in press) Stern (1993)	Richardson & Currie (1993)	
Organic volatiles: • **benzene & chlorinated solvents** • **trihalomethanes**	Hertzman et al. (1987) Morris et al. (1992)	Campbell (1993), MOEE (1994)	
Persistent organochlorines: • **dioxins/furans** • **DDT/organochlorine pesticides)** • **PCBs**	Fein et al (1984) Jacobson et al. (1984 & 1988)	Birnbaum (1993) Foran et al. (1989)	Ritter (1994)
Pesticides: • **organophosphates/carbamates & fungicides**	Fiore (1984)	Mitchell et al. (1987)	
Radioactive: • **radon** • **tritium**		Lubin (1994) ACES (1994)	
Other: • **uv-B** • **fluoride** • **nitrates**		Levallois & Phaneuf (1994)	OTFPPC (1995) Limeback (1993)

considerable assumptions are required, particularly with respect to physical environment non-occupational exposures. Expert groups, such as that brought together by the International Agency for Research in Cancer, have used such methods to estimate the theoretical preventability of cancers (Tomatis 1990). Miller (1992) carried out a similar process for Canada, examining a series of actions that might reduce incidence of cancer and comparing the reductions to those potentially preventable based on intercountry comparisons of incidence. Melanoma related to ultraviolet radiation stands out (40% reduction) although exposure is only one factor related to melanoma risk.

The thinning of the stratospheric ozone layer over the Great Lakes basin may be associated with increases in skin cancer and cataracts over time (Last 1993). We do not know the trend in personal exposure to sunlight in the Great Lakes basin, but the role of ultraviolet exposure from sunlight in skin cancer is well established (Ontario Task Force on the Primary Prevention of Cancer 1995).

However, some important findings based on risk assessment and epidemiological evidence were not included in these reviews. The contribution of radon exposure to lung cancer in the non-occupational context are a prime example (Lubin 1994). Radon is a gas that comes from the natural environment into homes and buildings and concentrates in indoor air (the risk related to concentration in outdoor air is extremely low). Radon could be a problem in the portion of the Great Lakes basin that is on the Canadian shield, but it is also a community concern in the Port Hope area. Tritium is a radioactive substance found especially in areas adjacent to nuclear power plants in Canada because of the use of heavy water in CANDU reactors (ACES 1994). The Advisory Committee on Environmental Standards (ACES) in Ontario recommended that the objective for tritium in drinking water be immediately reduced to 100 becquerels/litre (Bq/L) (in response to the recommendation by the Ontario Ministry of Environment and Energy to reduce the current objective from 40,000 Bq/L to 7,000 Bq/L) and be further reduced to 20 Bq/L within five years. Tritium concentrations in some drinking water supplies currently exceed the 20 Bq/L level from time to time. This recommendation was made on the basis that tritium is a human carcinogen and that the same level of acceptable risk should be applied to it as to other chemicals that are human carcinogens. Exposure occurs primarily through drinking water but exposure also occurs through air and the food chain.

Cancer risks related to ambient air pollutants at levels of one case per 100,000 exposed or greater are well covered in the Windsor Air Quality Study (MOEE 1994) and the review of the outdoor air quality in the City of Toronto (Campbell 1993). The major agents are benzene, 1,3-butadiene (from car exhaust), chromium VI and chlorinated solvents. Cancer risks for diesel fumes are well established (Carey 1987) but the risk at ambient levels of exposure are not known.

Trihalomethanes are known to be carcinogenic in animals and are generated in the chlorination process for drinking water. The major public health benefits of treating water with chlorination are well recognized (see Bellar et al. 1974). There is a strong epidemiologic evidence with respect to drinking water is increased risk of bladder and rectal cancer (Morris et al. 1992), based on a meta-analysis of case-control studies. Most recently there is evidence for a dose-related, significantly increase risk for colon and bladder cancer related to trihalomethanes in Ontario drinking water (GLHEP 1996) The proportions of cancers attributable to drinking water would be very low, but because much of the Great Lakes population drinks chlorinated water, the absolute numbers could be important. Further exploration of the risks and benefits to human health of chlorination and its alternatives are clearly warranted. We recommend that the IJC support investigations of the risks and benefits with respect to human health of chlorination and its alternatives because of the reliance of communities on the Great Lakes for drinking water.

Emerging literatures such as that linking persistent organochlorine pesticide exposure and breast cancer (Wolff et al. 1993; Kreiger et al. 1994) have not been fully incorporated into standard cancer risk estimation partly due to the ongoing controversy as to the significance of these findings (Ritter 1994). Risk assessment techniques have been used to estimate the cancer impact of eating Great Lakes fish contaminated with persistent organochlorines (Foran et al. 1989; U.S. EPA 1992). Based on DDT and dieldrin levels in the fish and consumption rates, increases in cancer risk for various concentrations were calculated. Yet these estimates are difficult to relate to particular areas unless distributions of fish consumption are known, data often of variable quality and representativeness (Ebert et al. 1994).

There is significant public concern regarding exposure to currently used pesticides. Organophosphate pesticides are used in institutions to control pests like cockroaches.

Although case reports for health effects related to exposure do exist, these effects in the majority of the concerned population likely fall in the category of environmental hypersensitivity. There is evidence that aldicarb, a carbamate pesticide, may impair immune function (Fiore et al. 1986). This exposure has occurred through well-water in Wisconsin. The International Agency for Research on Cancer (IARC) has classified several herbicides as possible human carcinogens and the recent report of the Ontario Task Force on the Primary Prevention of Cancer (1995) has recommended reasonable and measurable timetables to sunset these herbicides. Some fungicides have been shown to be carcinogenic in animals and significant exposure can occur through food, such as the consumption of pick-your-own strawberries (Mitchell et al. 1987). Use of these fungicides is now restricted in Canada and the United States.

The established effect of dioxins in animal models and the probable effects of DDT, PCBs and other persistent organochlorines on the immune system are likely by an endocrine modulation effect. (Birnbaum 1993; GLSAB 1995). Exposure to dioxin is primarily through the food pathway (Davies 1988). Potentiation of the immune system, i.e. allergic effects, has been considered with respiratory system effects, e.g. asthma.

Neurobehavioural effects include deficits that result from in utero exposure and possible direct effects related to exposure from industrial waste sites. The neurobehavioural effects of low levels of lead exposure are now established as an important public health problem (Needleman and Bellinger, 1991). Mercury is known from environmental disasters to produce neurobehavioural deficits in children, and modelling of fish consumption and mercury intake from fish is feasible (Richardson and Currie, 1993). A recent evaluation of the human epidemiologic evidence for setting the reference dose for methylmercury intakes suggests that current guidelines are too high (Stern 1993). Application of a lower daily intake criterion would likely increase fish advisories related to methylmercury in the Great Lakes basin. The role that aluminum exposure primarily through drinking water may have in the development of Alzheimer's disease has been extensively reviewed (Nieboer et al. 1995). Although there are weaknesses in the epidemiological evidence, other scientific evidence indicates that a possible role for aluminum cannot be ruled out. Effects of exposure to organic solvents from waste dumps have been documented (Hertzman et al. 1987). Infants of mothers consuming PCB contaminated fish were smaller than controls and had behaviourial deficits and impaired visual recognition (Fein et al. 1984; Jacobson et al. 1984; Jacobson and Jacobson, 1988), but the significance of these findings is still hotly debated.

Determination of the burden of reproductive problems at the levels of exposure thought to exist among human populations in the Great Lakes basin is fraught with uncertainties that have been highlighted in the Great Lakes Water Quality Board Seventh Annual Report (IJC 1994). Reproductive outcomes refer to a range of health problems, most notably birth defects and impact on fertility. Cadmium, lead, mercury and chlorinated solvents are known to be toxic to human reproduction but at levels considerably above those found from environmental exposure in the basin. Controversy has surrounded the attribution of reported reductions of sperm counts in industrialized countries to increasing exposure to exogenous (from outside the human body) estrogens such as nonylphenols, phthalates and persistent organochlorines (Carlsen et al. 1992; Bromwich et al. 1994; Auger et al. 1995). Studies are underway to examine the levels of contaminants in a range of angler, minority and other populations in the basin (ATSDR 1994) and new sensitive outcomes are being examined in relation to these levels (e.g. time to pregnancy). Some potential health effects, such as changing the frequency of behaviours more common in boys or girls (dimorphic behaviours) possibly related to environmental estrogens, still remain unexamined. This uncertainty makes attribution of a certain burden of disease too difficult to determine, though the worry engendered by concerns about pervasive environmental exposures constitutes a continuing source of distress to couples of reproductive age and their health providers (Drs. Henry Muggah, Salim Daya and John Collins, McMaster University, personal communications).

Assessment of the role of air pollution in admissions and deaths for cardio-respiratory illnesses has advanced considerably over the past decade. A series of studies, including one in Detroit, have found increases in deaths associated with small increases in levels of particulates which can be inhaled fully into the lungs (particulate matter of 10 microns or less, PM-10) and no thresholds for such effects (Schwartz 1991; Dockery and Pope 1994). Similarly, subjecting environmental data on air pollution and hospital admission data to advanced time series analyses, Burnett et al. (1994) were able to show increases above baseline admission rates attributable to ambient air pollution, ozone and sulphates (SOx). Sulphates in air are widely monitored in Ontario, and so may

Table V. Percentage of Respiratory Hospital Admissions[a] Associated with Air Pollution by Age and Disease Group

AGE (years)	DISEASE GROUP			
	Asthma (493)[b]	COPD (490-492, 494, 496)[b]	Infection (466, 480-486)[b]	All diseases
0-1	13.0* (5.2)	-15.7** (1.3)	19.1*** (6.7)	14.8*** (13.2)
2-34	5.5* (22.8)	23.8* (1.3)	4.4 (8.3)	5.5* (32.4)
35-64	9.8*** (8.8)	8.6 (7.1)	3.1 (8.1)	7.2*** (24.0)
65+	7.0 (5.1)	6.0** (17.1)	2.5 (15.7)	4.3* (37.9)
All ages	7.1*** (41.9)	5.8** (26.8)	4.3* (38.8)	5.8*** (107.5)

a (Ozone)lag1+$_{lag3}$ potency x 50 ppb + sulphate$_{lag1}$ potency x 5.3 $_{\mu}$g/m3
b ICD codes
* P < 0.05 (two sided)
** P < 0.01 (two sided)
*** P < 0.001 (two sided)

Note: Average number of daily admissions among all 168 hospitals in parenthesis

Burnett et al. (1984)

be an indicator of acid aerosol or PM-10 exposure as well as any effects of sulphates themselves. These effects were present only for the warm months of May through August. Infants up to one year of age were the most affected with 14.8 percent of all admissions to hospital for respiratory illnesses attributable to ozone or sulphate air pollution (see Table V). Given the major role of air pollution in environmental burden of illness, extrapolation of these figures to particular Areas of Concern should be possible based on local air pollution data collected by provincial or state authorities.

Diseases involving infection of the stomach and intestines due to foods and water contaminated by micro-organisms is another major category for which attribution to environmental exposures is routinely made by public health authorities (Todd 1991). Outbreaks from contamination of municipal water supply systems by protozoa (e.g. Moorehead et al. 1990) have constituted the largest clearly identifiable human burden of acute illness based on use of water from the Great Lakes or waters flowing into them. Both Milwaukee (MacKenzie et al. 1994), drawing from Lake Michigan, and Waterloo, drawing from the Grand River which flows into Lake Erie, have experienced difficulties controlling outbreaks of contamination by cryptosporidium species. These outbreaks are linked to sources of contamination within watersheds that cannot be managed efficiently and effectively at the point of water treatment plants but are better dealt with by watershed management schemes (Doug Sider, personal communication). Exposures to human and animal waste-contaminated waters during swimming (Fleisher et al. 1993) also results in gastrointestinal illness.

Finally a heterogeneous group of potential health impacts should be noted. Fluoride exposure in the basin occurs primarily through drinking water as prophylaxis against caries. It may be a problem for healthy teeth if the exposure is either too high or too low (Limeback 1993). Nitrates in drinking water can produce methaemoglobinaemia in young formula-fed infants if concentrations exceed 10 me/1. The risks associated with nitrates in drinking water have been reviewed for the Quebec population (Levallois & Phaneuf, 1994). Similar risks are likely in the Great Lakes basin.

It is beyond our scope here to discuss the burden of illness related to environmental hypersensitivity, an "illness" that has been increasingly attributed to physical environments (Ashford and Miller, 1991) but that is likely associated with specific social environments as well. A set of psychosocial impacts (stress, anxiety, worry) may not be recognized as "disease" but may be significant in people's experiences of an environmental exposure (Edelstein 1988; Taylor et al. 1993). Other interpretative models than traditional epidemiological ones are required to understand the linkages between such "illnesses" and ecosystem parameters. Other investigative methods, based more on qualitative traditions, are also required (Eyles et al. 1993; Cole and Eyles, 1995).

A variety of methods may therefore be required to collect and interpret data on burden of illness. Recent work has emphasized the framing of data for assessing population health impacts e.g. WHO's (1987) environmental health impact assessment (EHIA). The steps required in a EHIA are:

- assess direct impact on environmental parameters
- assess indirect impact on environmental parameters
- screen environmental parameters that have health significance
- assess increase in exposure
- assess increase in exposure in risk-group populations
- assess health impacts (mortality and morbidity)

All these are generally based on assumption and require specific measurement tools. Judgement on attribution of the health consequence or health risk is ultimately required. Experts from different fields have been shown to differ in their attributions of risk. Further support is given to the need for a cross-disciplinary framework of decision-rules in which to evaluate weight of evidence scientifically to facilitate decisions to act on human health burdens of illness due to environmental exposures. This forms part of the evidence of impact on human well-being, to which we now turn as the environmental conditions for well-being.

Environmental Conditions of Well-Being

What are the demands that human beings impose on society to shape their conditions and ensure their well-being? Cantril (1965) suggests the following:

1. Human beings require the satisfaction of survival needs,
2. Human beings need a sense of both physical and psychological security to protect gains already made and to assure a beachhead from which further advances can be staged,
3. People crave sufficient order and certainty in life to enable them to judge with fair accuracy what will or will not occur if they do or do not act in certain ways,
4. Human beings continuously seek to enlarge the range and to enrich the quality of their satisfactions,
5. Human beings are creatures of hope and are not genetically designed to resign themselves,
6. Human beings have the capacity to make choices and the desire to exercise this capacity,
7. Human beings require freedom to exercise the choices they are capable of making,
8. Human beings want to experience their own identity and integrity, more popularly referred to as the need for personal dignity,
9. People want to experience a sense of their own worthwhileness,
10. Human beings seek some value or system of beliefs to which they can commit themselves, and
11. Human beings want a sense of certainty and confidence that the society of which they are a part holds out a fair degree of hope that their aspirations will be fulfilled.

These ideas have been generalized in notions of the good or great society, descriptions of which came easier to people in the 1930s and 1960s that they perhaps do today. As President Johnson (1964, 2) wrote:

> *The Great Society is a place where the least among us will find contentment, and the best among us can find greatness. All of us will respect the dignity of the one and admire the achievement of the other.*

Lippmann (1937, 274) comments on reconciling conflicts in a "good or well society" that spring from a diversity of values, beliefs and positions:

> *It requires much virtue to do that well. There must be a strong desire to be just. There must be a growing capacity to be just. There must be discernment and sympathy in estimating the particular claims of divergent interests. There must be moral standards which discourage the quest of privilege and the exercise of arbitrary power. There must be resolution and valour to resist oppression and tyranny. There must be patience and tolerance and kindness in hearing claims, in argument, in negotiation, and in reconciliation.*
>
> *But these are human virtues; though they are high, they are within the attainable limits of human nature as we know it. They actually exist. Men [sic] do have these virtues, all but the most hopelessly degenerate, in some degree. We know that they can be increased. When we talk about them we are talking about virtues that have affected the course of actual history, about virtues that some men have practised more than other men, and no man sufficiently, but enough men in great enough degree to have given mankind here and there and for varying periods of time the intimations of a Good Society.*

Today we argue for the restitution of the conditions necessary for a good society (see Bellah et al. 1991). But as in the 1930s and 1960s, there is recognition of human diversity and the problems that may bring. For our discussion, diversity means that there is not one set of values or goals. Further, it means that agreement on the nature and content of society or social systems seems unlikely. But there is broad agreement on the conditions necessary for well-being (the individual equivalent of the good society) in countries like Canada. A well society is one in which people can meet their basic needs; where poverty has been reduced; where people are socially and economically mobile and respectful of the dignity of others; and where they have access to good services in a stable, democratic and participatory environment (Eyles 1986, 439). Quality of life is seen as the psychological, individual aspects of social well-being. It reflects a state of mind, dependent on socio-economic position and individual attributes. A high quality of life may, therefore, be based on an unthinking acquiescence to the prevailing order of things. In a more general sense, quality of life can take environmental factors into account — pollution, energy and diet (Eyles 1986, 382). Two fundamental dimensions are, therefore, involved in encapsulating a good society:

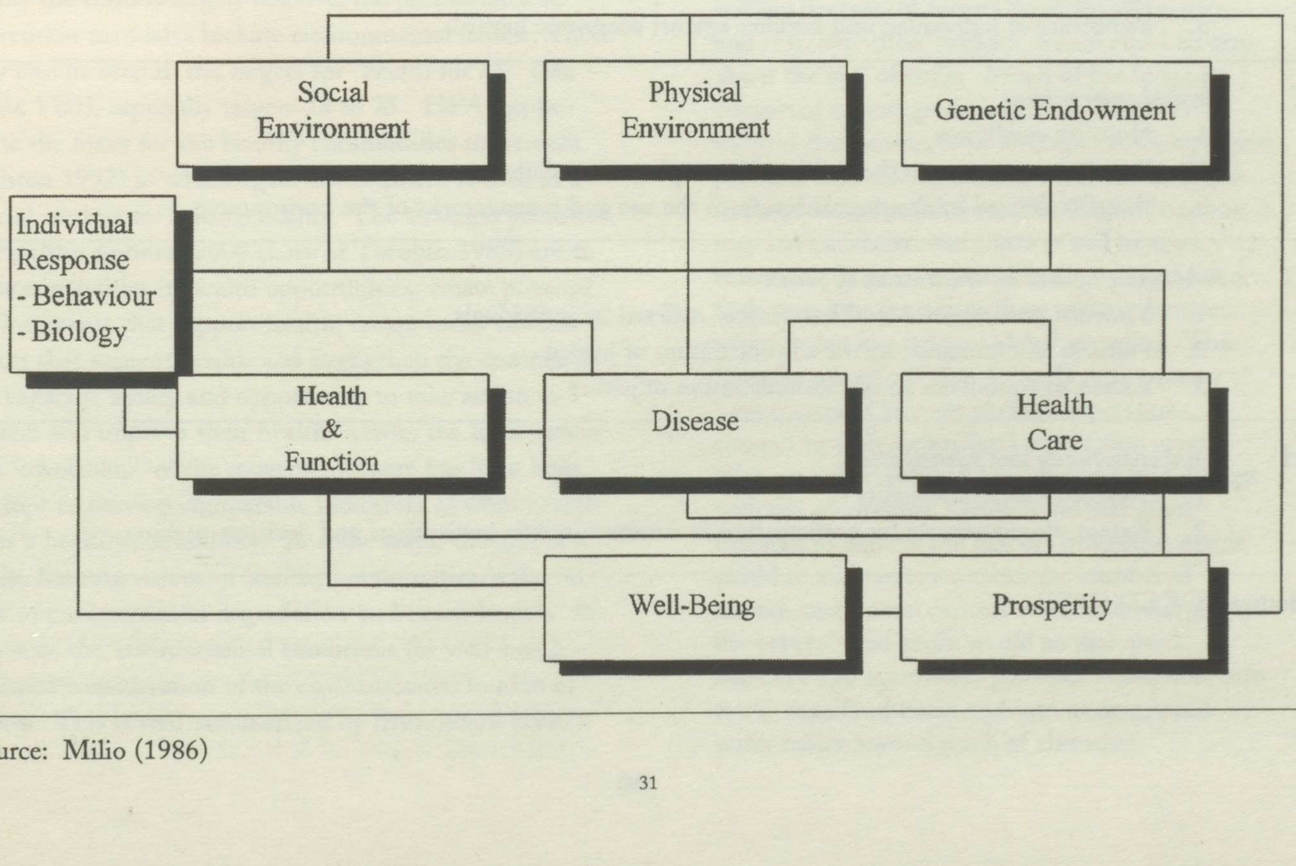
- an internal psycho-physiological component representing the sense of well-being, satisfaction or gratification or their opposites, and
- the external environment (made up of the domains of social life) that impinges on the individual's ability to shaping his/her living conditions.

Dalkey and Rourke (1973) argue that quality of life always means a person's sense of well-being, satisfaction or dissatisfaction with life, or happiness or unhappiness, measurable in terms of general, self-rated well-being measures (see section V).

In much work the domains of social life are seen as concerns. The OECD (1973, 8), thus focused on social concerns. A social concern was defined as "an identifiable and definable aspiration or concern of fundamental and direct importance to human well-being." Table VI lists those concerns. Further, Smith (1973) produced general criteria of well-being based on a critical review and appraisal of the social science literature (Table VII).

This approach of examining environment as one of the conditions for human health has been taken up by the Premier's Council in their "nurturing health" document (Ontario 1991). In this, a model developed by Evans and Stoddart (1990) is used to put forward the importance of social and physical environments (Figure VIII). Physical environment is seen quite narrowly in terms of occupational hazard and road traffic accidents. Later work by the Council (Ontario 1993) did broaden environment to include land-use, living space and ecosystem. In that regard, it became a broad-based advocacy document similar to the international texts (WHO 1992).

Figure VIII. Producing Health, Consuming Health Care



Source: Milio (1986)

Table VI: List of Social Concerns Common to Most OECD countries

A *Health*

1. Probability of a healthy life through all stages of the life cycle
2. Impact of health impairment on individuals

B *Individual development through learning*

1. Acquisition by children of the basic knowledge, skills and values necessary for their individual development and their successful functioning as citizens in their society
2. Availability of opportunities for continuing self-development and the propensity of individuals to use them
3. Maintenance and development by individuals of the knowledge, skills and flexibility required to fulfil their economic potential and to enable them to integrate themselves in the economic process if they wish to do so
4. Individual satisfaction with the process of individual development through learning while s/he is in the process
5. Maintenance and development of the cultural heritage relative to its positive contribution to the well-being of the members of various social groups

C *Employment and quality of working life*

1. Availability of gainful employment for those who desire it
2. Quality of working life
3. Individual satisfaction with the experience of working life

D *Time and leisure*

1. Availability of effective choices for the use of time

E *Command over goods and services*

1. Personal command over goods and services
2. Number of individuals experiencing material deprivation
3. Extent of equity in the distribution of command over goods and services
4. Quality, range of choice and accessibility of private and public goods and services
5. Protection of individuals and families against economic hazards

F *Physical environment*

1. Housing conditions
2. Population exposure to harmful and/or unpleasant pollutants
3. Benefits derived by the population from the use and management of the environment

G *Personal safety and administration of justice*

1. Violence, victimization and harassment suffered by individuals
2. Fairness and humanity of the administration of justice
3. Extent of confidence in the administration of justice

H *Social opportunity and participation*

1. Degree of social inequality
2. Extent of opportunity for participation in community life, institutions and decision-making

Source: OECD (1973).

Table VII: General Criteria of Social Well-being

I. *Income, wealth and employment* i. Income and wealth ii. Employment status iii. Income supplements	V. *Social order (or disorganization)* i. Personal pathologies ii. Family breakdown iii. Crime and delinquency iv. Public order and safety
II. *The living environment* i. Housing ii. The neighbourhood iii. The physical environment	VI. *Social belonging (alienation and participation)* i. Democratic participation ii. Criminal justice iii. Segregation
III. *Health* i. Physical health ii. Mental health	VII. *Recreation and leisure* i. Recreation facilities ii. Culture and the arts iii. Leisure available
IV. *Education* i. Achievement ii. Duration and quality	

Source: Smith (1973, 70)

The salience of human health as well-being has been given added impetus by similar notions being put forward by WHO (1981; 1985), i.e. a three-pronged health for all (HFA) strategy, with the component parts being promotion of life-styles conductive to health, prevention of preventable conditions, and rehabilitation and health services. While the third is largely reactive, the promotion and prevention mandates include environmental issues. These may also be seen in the targets for "health for all" (see Table VIII), especially targets 18 to 25. HFA has become the focus for the healthy communities movement (Ashton 1992) in which again environment is seen as a crucial context for human health. The strategic priorities of Healthy Toronto 2000 (City of Toronto 1988) are to reduce inequities in health opportunities, create physical environments that support health, create social environments that support health and strengthen the community's capacity, ability and opportunity to take action to protect and improve their health. Given the local nature and "ownership" of the movement, there has been little attempt to develop comparable indicators of what constitutes a healthy community. In some ways, though, one of the framing visions of healthy communities is the impact of environmental degradation on human health. In this way, the environmental conditions for well-being subsume consideration of the environmental burden of illness. This is well-summarized by Brundtland (1987):

There are also environmental trends that threaten to radically alter the planet, that threaten the lives of many species upon it, including the human species. Each year another 6 million hectares of productive dryland turns into worthless desert. Over three decades, this would amount to an area roughly as large as Saudi Arabia. More than 11 million hectares of forests are destroyed yearly, and this, over three decades, would equal an area about the size of India. Much of the forest is converted to low-grade farmland unable to support the farmers who settle it. In Europe, acid precipitation kills forests and lakes and damages the artistic and architectural heritage of nations; it may have acidified vast tracts of soil beyond reasonable hope of repair. The burning of fossil fuels puts into the atmosphere carbon dioxide, which is causing gradual global warming. This "greenhouse effect" may by early next century have increased average global temperatures enough to shift agricultural production areas, raise sea levels, to flood coastal cities, and disrupt national economies. Other industrial gases threaten to deplete the planet's protective ozone shield to such an extent that the number of human and animal cancers would rise sharply and the oceans' food chain would be disrupted. Industry and agriculture put toxic substances into the human food chain and into underground water tables beyond reach of cleansing.

Table VIII: Focus of Targets for "Health For All" by the Year 2000 in Europe

Targets 1-12: Health For All
1. Equity in health
2. Adding years to life
3. Better opportunities for the disabled
4. Reducing disease and disability
5. Eliminating measles, polio, neonatal tetanus, congenital rubella, diphtheria, congenital syphilis and indigenous malaria
6. Increased life expectation at birth
7. Reduced infant mortality
8. Reduced maternal mortality
9. Combating disease of the circulation
10. Combating cancer
11. Reducing accidents
12. Stopping the increase in suicide

Targets 13-17: Life-styles Conducive to Health For All
13. Developing healthy public policies
14. Developing social support systems
15. Improving knowledge and motivation for healthy behaviour
16. Promoting positive health behaviour
17. Decreasing health-damaging behaviour

Targets 18-25: Producing Healthy Environments
18. Policies for healthy environments
19. Monitoring, assessment and control of environmental risks
20. Controlling water pollution
21. Protecting against air pollution
22. Improving food safety
23. Protecting against hazardous wastes
24. Improving housing conditions
25. Protecting against work-related health risks

Targets 26-31: Providing Appropriate Care
26. A health care system based on primary health care
27. Distribution of resources according to need
28. Re-orientating primary medical care
29. Developing teamwork
30. Co-ordinating services
31. Ensuring quality of services

Targets 32-38: Support for Health Development
32. Developing a research base for health for all
33. Implementing policies for health for all
34. Management and delivery of resources
35. Health information systems
36. Training and deployment of staff
37. Education of people in non-health sectors
38. Assessment of health technologies

Source: WHO (1985)

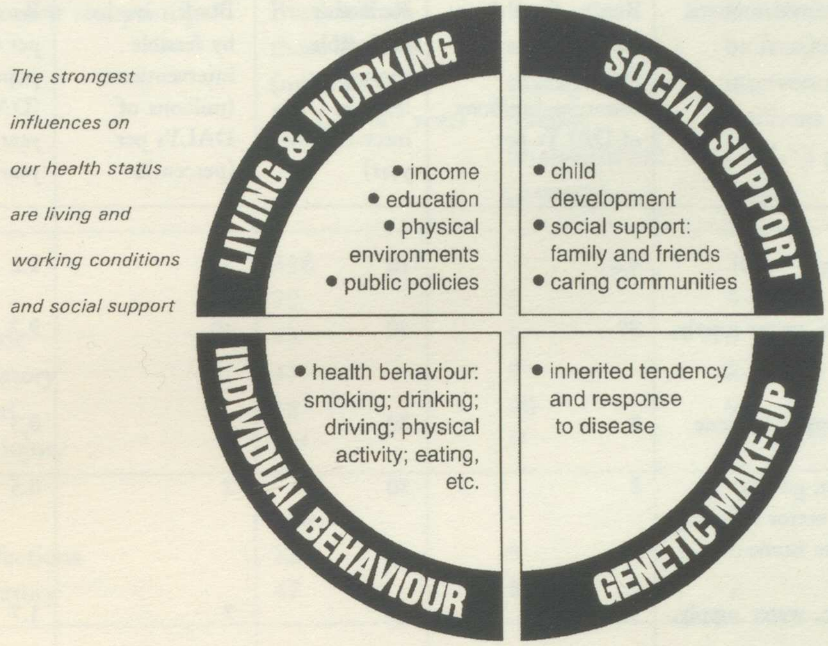
Discussion

How significant then are environmental burdens of illness or environmental conditions for well-being compared respectively to other burdens and other conditions? We do not feel that it is possible to provide an answer to the question concerning conditions. Human adaptability or capacity to innovate means that a good life can be lived in a variety of the environmental settings. The interactive nature of the social conditions in these settings further complicates the picture (see Figure IX).

Interactions between burdens and human resistance and resilience make it difficult to attribute ill-health to environment as opposed to other factors in general (see above). Characterizing the role of physical environments as determinants of human health has been a preoccupation of international and national bodies. Recent examples include the work of the WHO Commission on Health and Environment (1992) which took a predominantly media based approach and "A Vital Link" (Health and Welfare Canada 1992) which structured its scoping around various health problems and exposures. One of the few attempts to estimate a narrowly defined environmental burden of illness at a global scale (World Bank 1993) provides estimates for the health impact of household environments (Table IX), occupational environments and urban air (Table X). Most of those attributed to households are in fact the result of community — local environment level interactions. All impacts have been converted to DALYs or disability adjusted life years which incorporate both the effects of morbidity (sickness) and mortality (deaths). Included are a mix of specific diseases for which life cycles of parasites in the environment are known (e.g. trachoma) and non-specific conditions which may have multiple causes (e.g. chronic respiratory disease). Such an approach could constitute an interesting exercise in the Great Lakes basin, if sufficient relevant exposure data were available. It would build on previous work done by U.S. EPA (1992).

But these exercises must be located within the potential health impacts of larger environmental changes as noted by international commissions (e.g. Brundtland 1987) and human epidemiologists struggling to adapt their methods to the new challenges (McMichael 1993; Last 1993). Table XI sets out possible adverse effects on health, most of which are difficult to frame with traditional epidemiological methods but which may be monitored by environment and health indicator approaches to which we will turn in section V.

Figure IX. The Four Quadrants of Health and Well-Being



Source: Public Consultation Document, Nurturing Health, Premier's Council, Toronto, 1994

Despite the difficulties of attributing a specific proportion of overall burden of illness to degradation of the environment or ecosystem, human health is a vital consideration in the ecosystem health paradigm. Ecosystem health internalizes human health and well-being as part of the environment while a human health focus internalizes environment for individual and community well-being. The strength of the metaphor or paradigm re-emerges. Ecosystem health sees humans as integral parts of nature. This resonates strongly with core values about ourselves, our identity and our place-in-the-world. The clean or the pure and the unclean or impure are seen as vital parts of identity construction and maintenance (Clark and Davis, 1989). This is played out in our relations with the environment or ecosystem. Ecosystem health emphasizes the importance of the clean or pure for us and the environment. "Dirt is essentially disorder... In chasing dirt, in papering, decorating and tidying, we are not so much governed by anxiety to escape disease, but are possibly re-ordering our environment, making it conform to an idea" (Douglas 1966, 12). While dirt is not necessarily equal to disorder, it is a potential pollutant which is strongly felt, particularly in North American culture (see Meigs 1978). In this culture, "secular defilement" — a state of perceived uncleanness resulting from contact between a person and an object or activity believed to be "dirty" or polluting — is especially felt, e.g. the NIMBY syndrome, the fights against waste and waste disposal. But defilement can be used by the powerless to challenge the dominant ways of thinking and acting (see Corbin 1986) so there is not universal agreement. But the insertion of human health and well-being into concerns about the environment through ecosystem health ups the ante by trying to define and shape lives through appeals to self-interest (but not altruism — see above). We concur with the assertion but recognize the caution with which the coupling of human health and ecosystem health must be viewed. We must not uncritically accept the coupling because of the strength of the appeals or the resonance with ourselves. The metaphoric power of ecosystem health will always point to seeing the coupling as "natural." We therefore recommend the recognition of the role of defilement, pollution, health and environment in identity. Given that recognition, it behooves us to ask continuously: how is human health relevant to these ecosystem issues? What "evidence" (scientific or philosophic) underpins the connection of human health and ecosystem health? and how might we judge the significance of any identified connection? In answering such questions through identifying plausible indicators, we must always be aware of the normative basis and power of science, despite its limited ability to quantify an environmental burden of illness.

Table IX: Estimated Burden of Disease From Poor Household Environments in Demographically Developing Countries, 1990, and Potential Reduction Through Improved Household Services

Principal diseases related to poor household environmentsa	Relevant environmental problem	Burden from these diseases in developing countries (millions of DALYs per	Reduction achievable through feasible interventions year)	Burden averted by feasible interventions (millions of DALYs per (percent)b	Burden averted per 1,000 population (DALYs per year) year)
Tuberculosis	Crowding	4.6	10	5	1.2
Diarrhea[c]	Sanitation, water supply, hygiene	99	40	40	9.7
Trachoma	Water supply, hygiene	3	30	1	0.3
Tropical cluster[d]	Sanitation, garbage disposal, vector breeding around the home	8	30	2	0.5
Intestinal worms	Sanitation, water supply, hygiene	18	40	7	1.7
Respiratory infections	Indoor air pollution, crowding	119	15	18	4.4
Chronic respiratory diseases	Indoor air pollution, crowding	41	15	6	1.5
Respiratory tract cancers	Indoor air pollution, crowding	4	10[e]	*	0.1
All the above	Indoor air pollution, hygiene	338	-	79	19.4

* Less than one.

a. The diseases listed are those for which there is substantial evidence of a relationship with the household environment and which are listed in Appendix B. Examples of excluded conditions are violence related to crowding (because of lack of evidence) and guinea worm infection related to poor water supply (not listed in Appendix B).

b. Estimates derived from the product of the efficacy of the interventions and the proportion of the burden of disease that occurs among the indoor air pollution, and crowding of the kind being made in poor communities in developing countries.

c. Includes diarrhea, dysentery, cholera, and typhoid.

d. Diseases within the tropical cluster most affected by the domestic environment are schistosomiasis, South American trypanosomiasis, and Bancroftian filariasis.

e. Based on very inadequate data on efficacy.

Note: The demographically developing group consists of the demographic regions of Sub-Saharan Africa, India, China, Other Asia and islands, Latin America and the Caribbean, and Middle Eastern crescent.

Table X: Estimated global burden of disease from selected environmental threats, 1990 and potential worldwide reductions through environmental interventions

Type of environment and principal related diseases[a]	Burden from these diseases (millions of DALYs per year)	Reduction achievable through feasible interventions[b] (percent)	Burden averted by feasible interventions (millions of DALYs per year)	Burden averted per 1,000 population (DALYs per year)
Occupational	318	-	36	7.1
Cancers	79	5	4	0.8
Neuropsychiatric	93	5	5	0.9
Chronic respiratory	47	5	2	0.5
Musculoskeletal	18	50	9	1.8
Unintentional injury	81[c]	20	16	3.1
Urban air	170	-	8	1.7
Respiratory infections	123	5	6	1.2
Chronic respiratory	47	5	2	0.5
Road transport (motor vehicle injuries)	32	20	6	1.2
All the above	473[d]	-	50	10.0

a. The diseases shown are those for which there is substantial evidence of a relationship with the particular environment and which are listed in Appendix B.

b. Estimates derived from the product of the efficacy of the interventions and the proportion of the global burden of disease that occurs among the exposed. All estimates of efficacy are speculative and assume the implementation of known, feasible, and affordable interventions in the circumstances encountered in developing countries.

c. Computed by subtracting motor vehicle injuries (32 million DALYs) from all unintentional injuries (113 million DALYs).

d. Adjusted for double counting.

Source: World Bank (1993)

Table XI: Types of possible adverse effects upon health due to global environmental change.

		Type (direct, indirect), timing[a] (early, late) of adverse health effect			
Environmental change	Manifestation	Direct, early	Direct, late	Indirect, early	Indirect, late
Enhanced greenhouse effect	*Global warming and climate change*	Heatwave-related illness and deaths Natural disasters: cyclones, floods, landslides, fires		Altered distribution of vector-borne infectious diseases. Food shortages due to altered agricultural productivity	Reduced viability of edible fish in warmed oceans
	Sea-level rise	Increased risk of flash floods, surges	Inundation: social dislocation, sanitation breakdown, farm loss	Consequences of damage to foreshore facilities, roads, etc.	Destruction of wetlands — decline in fish stocks
Stratospheric ozone depletion	*Increased Uv-B flux at Earth's surface*	Sunburn, photo keratoconjunctivitis Suppression of immune system — increased risk of infection, cancer	Skin cancer Ocular effects: cataracts pterygium		Impaired growth of food crops and of marine micro-organisms (base of aquatic food web)
Acid aerosols (from combustion of sulphurous fossil fuels)	*Acid rain (and other precipitation)*	Possible effects on respiratory system		Killing of aquatic life — reduced food Impaired crop growth	Impairment of forest growth — reduced eco-system productivity
Land degradation: over-intensive agriculture and excessive grazing	*Erosion, sterility, nutrient loss, salinity chemicalization; desertification*	Decline in agricultural productivity	Rural depression — migration to fringes of cities (shanty towns) (see also bottom row)	Exposure to higher levels of pesticides and fertilizers; may also lead to toxic algal blooms in waterways	Consequences of silting up of dams and rivers
	Depletion of underground aquifers	Lack of well-water for drinking and hygiene	Decline in agricultural productivity		
Depletion of plants and animals; loss of biodiversity	*Destruction of habitat*	Deforestation: disruption of local culture and health	Shortage of edible species		Deforestation — greenhouse enhancement
	Loss of genetic diversity (species and strains); weakening of ecosystems			Loss of medicinal chemicals, and other health-supporting materials	Greater vulnerability of plants and livestock. Decline in vitality of ecosystems
Other effects of overpopulation, particularly in poor countries	*Proliferation of crowded urban slums and shanty towns (due to migration and high fertility)*	Infectious diseases Malnutrition Antisocial behaviours	Effects of breakdown of social organization		Various consequences of overload of local ecosystems

[a] the designations "early" and "late" are notional only, indicating the relative time of occurrence

Source: McMichael (1993)

V.

INDICATORS OF HUMAN HEALTH AND ECOSYSTEM HEALTH

In this section, we briefly review indicators in the domains of ecosystem health (environment) and human health. Over the last few years each of the domains has gradually incorporated indicators from the other domain, indicative of the convergence of understanding of the interconnectedness of environment and human health within ecosystems. However, this incorporation can give rise to problems in emphasis, validity and interpretation. We therefore examine some of the scientific issues in the use of indicators in the final part of this section.

Environmental Indicators

Information on the environment and systems for handling that information have experienced considerable growth over the last decade, initially for reports of the state of the environment (McRae 1992) or as a complement to widely used economic or social indicators (OECD 1993) but more recently as part of integrated approaches to ecosystems and the role of human activities as part of them (CCME 1994). Here we review some of these approaches emphasizing the ways in which they deal with health indicators.

State of the environment (SOE) reporting has been initiated at a variety of geographic scales. Globally, the United Nations Environment Programme in an SOE report (1991) included indicators of environmental pollution, climate, natural resources, populations/settlements, energy, transport/tourism, wastes, natural disasters, human health and international cooperation. The section on environmental pollution included data on chemical contaminants in food and dietary intake (e.g. cadmium), contaminants in human fluids (e.g. dioxins in breast milk) and excreta and exposure to ionizing radiation. Other exposure information can be found elsewhere in the document (e.g. access to safe drinking water in populations/settlements). Human illness and injury data included both directly relevant information (e.g. deaths and injuries from major chemical incidents) and data of unclear relevance (e.g. extensive tables of general mortality information by country with little relation to environmental variables).

Nationally, the Government of Canada SOE report (1991) presented indicators based on environmental media (e.g. air), resource sectors (e.g. mining), issues (e.g. toxic chemicals), and hydrological regions (e.g. Great Lakes). Human health considerations were woven into a number of the sections. Some examples include: public concerns about drinking water contamination with organic chemicals discussed in the chapter on freshwater (a media), including the changing approach to trihalomethanes; ground level ozone exposures in the Windsor-Quebec City corridor at levels known to have adverse effects on health in the chapter on energy (a resource sector); implications of contaminated fish consumption for neurobehavioural impacts in the Great Lakes basin chapter (a hydrological region); and a detailed discussion of the meaning and mechanisms of toxicity for both human and non-human species and the declines in ambient levels of metals, such as mercury in Lake St. Clair, and plateaued levels of some persistent organochlorines, such as 2,3,7,8-TCDD in trout in Lake Ontario, in the chapter on toxic chemicals (an issue). Environment Canada continues to issue periodic bulletins on subjects such as toxins in the environment, municipal water use, stratospheric ozone depletion and urban air quality. These are reissued whenever new data permit, usually annually. Human health considerations may be referred to but are not necessarily included as indicators, e.g. melanoma rates are not part of the bulletin on stratospheric ozone depletion.

SOE reporting is only under development in the province of Ontario and no U.S. states are currently engaged in a formal system. For the municipal level, Campbell et al. (1995) examined the literature, conducted case studies and surveyed cities across Canada. Their survey indicated the burgeoning of data collection and integration to obtain a picture of municipal environmental status. Their case studies noted a predominant focus on what they term "biophysical indicators" (n=226) which includes land use (e.g. open space), media (e.g. air quality) and stresses and responses (e.g. waste generation and recycling). Social indicators were next (n=35) followed by economic indicators (n=21). Few municipalities included health variables as SOE indicators. Those that did had general health

Source: McMichael (1993)

indicators (5/290) and one each for poisonings, motor vehicle accidents and air pollution effects.

A useful management framework was developed by Rapport and Friend (1979) working with Statistics and Environment Canada. They asked four questions: what is happening? (environmental conditions); why is it happening? (pressures/stresses on the environment); why is it significant ? (evaluation-not included in final model); and what are we doing about it? (management response). Campbell et al. (1995) provide an example of its application to environmental media (Table XII). The environmental condition boxes of the framework include the heterogeneous indicators that may both directly (e.g. number of smog episodes per year) and indirectly (e.g. percent change in hospital admissions due to asthma attacks) be related to the stress (e.g. percent increase in vehicle traffic per year). Similarly, some indicators (e.g. number of days beaches are closed to swimming) are as much a result of local health department management responses as the stress to the system (e.g. storm discharges to the lake).

The Great Lakes Science Advisory Board's (SAB) (1993, 42-7) report to the IJC provides a succinct summary of the nature, experiences and challenges of SOE reporting. Among their conclusions were:

Table XII. Condition-Stress-Management Model for Individual Environmental Models

Framework Component	Description	EXAMPLES OF INDICATORS: WATER	AIR	LAND
Condition	Responding environmental conditions	• (reduced) diversity of aquatic species • exceedances of water quality guidelines • number days beaches closed to swimming	• number smog episodes per year • trend in CO_2 levels • % change in hospital admissions due to asthma attacks	• landfill capacity remaining • toxicity of landfill leachate • per capita spending on waste management
Stress	Human activities that are stressing the environment	• concentration/loading of chemicals/bacteria in storm discharge to lake	• % increase in vehicle traffic per year	• household waste generation per capita • quantity of toxics generated in household waste per capita
Management Response	Management responses to the stresses and condition	• % of combined stormwater outflows that have had sanitary sewers separated	• implementation of vehicle testing program (% of sample population exceeding standards) • promotion of public transit use (change in modal split) • implementation of traffic management plans with new development	• % of population participating in blue box program • % of household wastestream composted and recycled • implementation of collection system for household toxics (quantity of toxics collected per annum; % of population participating

Source: Campbell et al. 1995

3. Inadequate understanding of the human-ecosystem interface: ...SOE reports are generally introduced with holistic concepts about links between humans and ecosystems, but their underlying premise is rarely pursued in actual analysis. ...At best, a trend analysis is presented of the human environment in its institutional context, e.g. agriculture, ...

7. Restrictive analytical boundaries of SOE reporting: Once one is drawn into the world where "everything is connected with everything else," category boundaries lose nearly all meaning. Nonetheless, a reporting process that ignores traditional categories like air, water and land can become confusing unless they are transcended by descriptions of the behaviourial characteristics of the system itself. In addition, one or several "objective functions" must be identified in order to develop selection criteria to observe factors assumed to be important influences on the state of the system....

Reflecting on the Great Lakes reporting experience in particular, the SAB expressed concern that despite a large amount of scientific data being produced by monitoring, surveillance and research programs, little effort had been devoted to data integration and synthesis. It recognized the initiative the IJC had taken in reporting on human and ecosystem health concerns but emphasized the need for Great Lakes Basin Ecosystem assessments to include human well-being, likely expanding "to whole communities, particularly in reference to native people, the urban poor and communities vulnerable to resource degradation and depletion."

Many Remedial Action Plan Stage 1 assessments have moved towards a community focus by including local history, data on the natural and social environment, foci on special groups (e.g. Mohawks in the St. Lawrence River RAP) and synthetic summaries of the issues and concerns (e.g. Remedial Action Plan Hamilton Harbour 1992). An example of how human health aspects are dealt with in this framework is provided by the Hamilton Harbour Stage 1 document. In the general description of the area, discussion is included on beach contamination, water quality at water supply intakes, contaminants in game bird and fish flesh, general health concerns and their relation to water quality in the harbour, public concerns about pollution and health more generally, and current programs. This list moves beyond the three classic management responses included in the IJC's list of impairments of beneficial uses: restrictions of fish and wildlife consumption, restrictions on drinking water consumption or taste and odour problems and beach closings. The environmental conditions section, however, is based on data availability. This section includes time and location specific faecal coliform counts (for beach closings), Ontario Drinking Water Surveillance Program results on about 160 chemical constituents at the water treatment plant intakes (drinking water quality) and species and location specific contaminant levels for persistent organochlorines and metals in game birds and fish flesh (for fish and wildlife restrictions). Local data were not available on local concerns about pollution and not used for other health impacts. The water rather than full ecosystem focus is clear despite the importance of airborne sources of loadings and the fact that human health in the watershed may be more affected by other pollutants. Overall human health and well-being have been minor in most RAP Stage 1 documents. This prompted a workshop on Integrating Human Health Considerations into RAPs (reported in GL SAB 1993, 37-38) which suggested incorporation of a wide range of human health indicators as is being increasingly carried out (Sandra Owens, Moe Hussain, personal communications). There was, however, little sense of data availability and or the evidence for environmental causation of human health outcomes (see below for fuller discussion).

At a larger geographic scale, state of the lake reports have been produced to synthesize information available through RAPs and independent sources. A good example is the Lake Ontario document (Rang et al. 1992) organized around a core inventory of impairments of beneficial uses. Innovatively, Rang et al. used quality criteria for the inclusion of different kinds of data, which is of key importance in determination of indicators from a scientific perspective (see below). Critical appraisal questions were developed for analytic measurements, toxicological studies, ecologic studies and epidemiologic studies.

Finally, at the basin level considerable work went into the synthesis of data on the presence and potential impacts of toxic chemicals within the Great Lakes basin (Environment Canada et al. 1991) with foci on contaminant levels in water and sediments, aquatic biota (mainly fish) and wildlife species (mainly birds) by lake or river (e.g. Lake Superior, Niagara River). It is instructive that the section on human contaminants takes a different approach, first examining contaminants in all the media which form pathways for human exposure (food, drinking water, air and soil) and then setting out data on contaminants in different human tissues (adipose, blood, breast milk and so on). In some sense this reflects the luxuries of focusing on a single species but it also reflects the wider range of locations of humans (including workplace environments), lower sampling frequencies and the greater importance of other routes of human exposure which may import contaminants into the basin (e.g. air and food).

Different approaches to different species are clear. The reporting of studies on fish considers a range of non-chemical factors and overall toxic effects before describing measurements at the molecular, cellular, individual, and population and community levels. That on wildlife species discusses methods for studying effects and then accounting for effects seen by species. That for humans reviews epidemiological studies of cancer and reproductive problems in general populations, followed by studies of outcomes in specific populations. The reasons for the different approaches are not clear, begging the question of ability to generalize across species. Why is thyroid size higher or lower in some bird species and not apparent in fish or human populations? Why are congenital malformations the hallmark of mutations in birds but far less apparent in fish and humans? Explorations of the use of bio-indicators (biochemical changes in the organs of indicator or sentinel non-human species) have tried to come to grips with such differences in proposing their use for monitoring the effects of reductions in levels of persistent toxic substances (Fox 1994).

Despite these concerns, the shift towards the inclusion of human health and well-being as part of ecosystem health is apparent in the Council of Great Lakes Research Managers report on a framework for the development of ecosystem health indicators (IJC 1991). Table XIII sets out a matrix of seven domains in which one is human health crossed by the kinds of measurements that can be applied to these domains. Quantity and quality are standard but addition of valuation costs and management are useful. Table XIV suggests study design and human health outcomes by body system, including neurotoxicity and immunotoxicity, which have analogies in the animal literature. Yet the human health outcomes remain more poorly documented and less clearly related to other aspects of the ecosystem than those using other species for reasons that section IV made clear.

The Ecosystem Objectives Work Group (1992) built on this work by including human health as one rubric alongside aquatic communities, wildlife, habitat and stewardship. Based on a workshop on Human Health Objective Indicators, the group proposed four indicators: 1) an environmental health indicator based on exceedances of established federal, provincial and state standards of contamination in different media; 2) a public perception indicator based on public surveys of perceived risks to health; 3) a body burden indicator of toxic contaminants in tissues; and 4) health effect indicators using existing databases on cancer and birth defects, recognizing the limitations involved in relating these to environmental exposures.

A U.S. intergovernmental group focusing on monitoring water quality has also developed a set of criteria for indicator selection, which it divided into scientific, practical and programmatic considerations (ITFM 1994) (Table XV). Although several similarities with the IJC criteria are apparent, the grouping is helpful in sorting out elements of justification for particular indicators.

Human Health and Social Status Indicators

Traditionally, health status measures in populations have relied on routinely collected data at international (Murnaghan 1981), national (Peron and Strohmenger, 1985) and more local (Chambers 1983) levels. Basic information on rates of death (mortality) by disease, age and sex may prove useful for comparisons across regions when environmental exposures are sufficiently high and regionalized to cause major effects. A good example is provided by Hertzman (1995) from Central and Eastern Europe, where levels of air pollution are an order of magnitude higher than in the Great Lakes region. After adjusting for district measures of mean income, mean car ownership, proportion of illegitimate [sic] births and abortion rates, rates of low birth weight (relative risk (RR) = 1.18), post-neonatal morality (RR=1.61) and infant mortality (RR= 1.38) were all significantly higher in former Czechoslovakia districts with the highest levels of air pollution compared with those with the lowest. Of note in this report is the lack of association between environmental pollution levels and some of the routinely collected health variables proposed in the workshop on incorporation of human health into ecosystem health (GLSAB 1993): e.g. adult rates of ischaemic heart disease and sex ratios of new births among others. If associations do not become clear in extremely polluted regions, associations are not likely to be found in the relatively less polluted Great Lakes basin.

Hospital utilization rates by age, sex and disease may also prove useful. A recent Canadian Atlas of Hospital Morbidity in the Great Lakes Region (Bureau of Chronic Disease Epidemiology 1993) noted potential areas with higher rates for some diseases. These facilitate the

Table XIII. Potential Indicators of the Response of Human Use to Environmental Degradation

	QUANTITY	QUALITY	VALUATION COSTS	MANAGEMENT
Commercial Fisheries Bird & Rapport, 1986	• stock, harvesting, recruitment estimates	• presence of preferred species • restriction on consumption • incidence of tainting, deformities	• shadow pricing: farm reared vs. feral fish • employment and payroll	• stocking • lamprey control
Drinking Water Wentworth et al. 1986	• stock, withdrawal, replenishment estimates	• treatment costs • chemical and bacterial standards violations • restriction on consumption • reported acute illness • user satisfactory*	• contingent valuation: willingness to pay and compensation for damage*	• treatment costs
Recreation Hunsaker & Carpenter 1990 Lichtkopper & Hushak, 1989	• visit counts: sport fishing, swimming, boating, bird watching, bird hunting • boat registration • marina and beach counts • marine vacancy rates	• incidence of fish consumption restrictions • incidence of contact sport restrictions • incidence of fish deformities or tainting • catch per unit effort	• employment and payroll • marine sales • admission fees • shadow valuation: pool construction vs. beach use	• stocking
Industrial, Energy and Agricultural Water Use	• stock, withdrawal, replenishment rates	• productivity, crop, livestock losses attributable to water quality problems • costs of pre-use treatment, descaling, defouling	• compensation for loss of use • increased product cost due to degradation	• cost of post-use treatment
Aesthetics	• subjective satisfaction • miles of shoreline	• incidence of objectionable odour* • incidence of turbidity • incidence of algal blooms	• shadow valuations: waterview vs. inferior real estate • contingent valuation willingness to pay and compensation for loss*	• landscape planning
Transportation Water Use	• water levels		• employment and payroll	• income loss due to restrictions on dredging • costs of disposal for contaminated dredge spoils • costs of pollution controls • costs of control of nuisance growths: macrophytes, zebra mussels
Human Health	• community level • native people	• perception of a healthy environment	• human welfare • social value	• medical costs • loss of human potential
Support of General Well-Being of Region • Traditional economic indicators (GNP, unemployment, income class distribution, etc.)				
Future Use • genetic poll for pharmaceuticals, genetic engineering, temperature buffer in global warming				

* Subjective evaluations, dependent on survey of shareholders

Source: IJC (1991)

Table XIV. Potential Indicators of the Response of Human Health to Environmental Degradation

A. STUDY DESIGNS — ASSESSMENT APPROACHES WITH DIFFERENT RECEPTOR ORGANISMS	
1. Epidemiological studies on exposed human populations (see March and Caplant, 1987)	a. Environmental studies b. Case control studies c. Cohort studies
2. Studies on sentinel species of exposed feral animals (see Gilbertson 1988; Colborn 1990)	a. Mammals, minks, voles b Birds, herring gulls, Forster's terns, eagles c. Fish, spottail shiners, brown bullheads
3. Studies on surrogate species of exposed laboratory animals (see Lave et al. 1988)	a. Mammals, mice, rats b Nonmammalian systems, tissue culture, bacteria (Ames assays), planaria, hydra, water fleas, frogs, fathead minnows
B. CATEGORIES OF INDICATORS	
1. Neurotoxicity (see Caplan and Marsh, 1987)	a In viva • regional incidence rates for multiple sclerosis, Parkinson's, amyotrophic lateral sclerosis • behaviourial assays, infant cognitive function, speech, gait, visual disturbance, headaches, memory function • biomarkers, biopsy and histopathology, visual-evoked response, electroencephalogram, positron emission tomography, CAT scan, electromyography b In vitro • cell culture excitability, synaptic potential, repetitive firing properties, nerve conduction velocity
2. Reproductive toxicity (see Caplan and Marsh, 1987)	a In vivo • regional incidence rates for birth defects, infertility, miscarriage, stillbirth, low birth weight • biomarkers, sister chromatid exchanges, sperm counts, motility and morphological abnormality
3. Carcinogenicity/mutagenicity/ genotoxicity (see Sandhu and Lower, 1987); Wang et al. 1987; Colborn 1990; Caplan and Marsh, 1987)	a. In vivo • regional incidence rates • biomarkers, DNA adducts, sister chromatid exchange, DNA unwinding, histopathology b. In vitro • histopathology of tissue cultures • Ames mutagenicity tests
4. Cardiovascular disease	a. In vivo • regional incidence rates
5. Immunocompetency	a. In vivo • blood cell counts

Source: IJC (1991)

generation of hypotheses as to environmental and social causes. Utilization rates are, however, subject to considerable variation based on facilities available and health practitioner guided utilization practices in different settings (Roos and Roos, 1994). For example, among Manitoba elderly patients reporting good or excellent health, the probability of being hospitalized could vary twofold depending on the practice style of their physician (Roos 1989). Burnett et al. (1994) using sophisticated analyses to link air pollution and hospital admissions (Table V), showed the percentage of all hospital admissions associated with air pollution among those 65 or older was 4.3

Table XV. Summary of Some Indicator Selection Criteria

CRITERIA/QUALITY	DEFINITION(s)
SCIENTIFIC VALIDITY (TECHNICAL CONSIDERATIONS)	
Measurable/Quantitative	Feature of environment measurable over time; has defined numerical scale and can be quantified simply
Sensitivity	Responds to broad range of conditions or perturbations within an appropriate timeframe and geographic scale; sensitive to potential impacts being evaluated
Resolution/Discriminatory Power	Ability to discriminate meaningful differences in environmental condition with a high degree of resolution; (high signal to noise ratio)
Integrates Effects/Exposure	Integrates effects or exposure over time and space
Validity/Accuracy	Parameter is true measure of some environmental condition within constraints of existing science
	Related or linked unambiguously to an endpoint in an assessment process
Reproducible	Reproducible within defined and acceptable limits for data collection over time and space
Representative	Changes in parameter/species indicates trends in other parameters they are selected to represent
Scope/Applicability	Responds to changes on a geographic and temporal scale appropriate to the goal or issue
Reference Value	Has reference condition or benchmark against which to measure progress
Data Comparability	Can be compared to existing data sets/past conditions
Anticipatory	Provides an early warning of changes
PRACTICAL CONSIDERATIONS	
Cost/Cost Effective	Information is available or can be obtained with reasonable cost/effort
	High information return per cost
Level of Difficulty	Ability to obtain expertise to monitor
	Ability to find, identify, and interpret chemical parameters, biological species, or habitat parameter
	Easily detected
	Generally-accepted method available
	Sampling produces minimal environmental impact
PROGRAMMATIC CONSIDERATIONS	
Relevance	Relevant to desired goal, issue, or agency mission e.g. fish fillets for consumption advisories; species of recreational or commercial value
Program Coverage	Program uses suite of indicators that encompass major components of the ecosystem over the range of environmental conditions that can be expected
Understandable	Indicator is or can be transformed into a format that target audience can understand (e.g. non-technical for public)

Source: ITFM (1994)

percent. Such a small increase could be easily masked by non-random distributions in practice style among physicians in any particular community. Similarly, a large increase in Table hospital admissions in a community could be inappropriately attributed to pollution effects when the source of variation was physician practice style.

Registries of birth defects usually are derived from hospital discharge diagnoses and vital statistics data. Johnson et al. (1992) have compiled such an atlas for Ontario. The significance of the variations is hard to determine, as is the overall birth defect rate in Ontario (37.6 cases/1,000 births) compared to other jurisdictions. Increased rates and risk can spuriously come from differences in ascertainment by physicians and coders in hospitals, random variation, combinations of the two, or true differences. Events for any specific malformation are sufficiently rare to make detection of elevated rates and risks difficult. In heavily polluted industrial cities of the Ukraine, average rates of congenital anomalies were 11.7 and 8.8 compared to 3.8/1000 in a less polluted city (Hertzman 1995). All these numbers are below Ontario rates, which may be explained by differences in classification. Of interest in the Ukraine were similar gradients for rates of multiple, dominant and x-linked anomalies not apparent among recessive anomalies. New mutations may be occurring. Such an analysis is relevant to potential effects of environmental pollution and can be applied to the congenital anomalies databases. It is best done by chart review, a time-consuming exercise presently used to compile the British Columbia congenital anomalies data-base (Darrell Tomkins, personal communication). Yet determination and measurement of relevant exposures is more difficult. Except in high exposure situations detection of a signal (a few cases) from the noise is difficult.

Cancer registries must rely on more varied sources and methods of reporting to build as complete a picture as possible of the numbers of new cases occurring each year (incidence). A cancer incidence atlas has been compiled for Ontario (Mills and Semenciw, 1992). Although data quality across regions in Ontario has been shown to be good and spatial aggregation occurred for about one-third of the site-sex combinations, considerable work remains to be done on the wide range of exposures that may be implicated (Walter et al. 1994). Studies of the association between proximity to nuclear plants and leukemia have shown a slight, but not statistically significant, trend toward increased leukemias (McLaughlin et al. 1991). Linkages with existing environmental data are possible, as exemplified by the series of studies linking trihalomethane concentrations in drinking water with colon or rectal and bladder cancer occurrence (Morris et al. 1992; GLHEP 1996), and increased rates of lung cancer (alone) for both sexes in highly polluted areas of former Czechoslovakia (Hertzman 1995). Demonstration of such associations in a defensible fashion when exposures are less intense and of variable latency, usually require case-control approaches which document exposures of interest and additional (often lifestyle) exposures which may confound the observed relationships. Methods for building up detailed exposure histories for population based case-control studies of cancer have been considerably advanced for occupational exposures to a range of potential carcinogens using expert hygienist coders (e.g. Siemiatycki et al. 1992) but are only now being developed across the range of carcinogenic exposures present in the ambient environment (Johnson et al. 1995).

Water-borne infectious diseases have a long history of mandatory reporting to public health authorities. Most important recently have been outbreaks due to less commonly controlled organisms like cryptosporidium (e.g. Waterloo, Ontario in 1993, Milwaukee; MacKenzie et al. 1994). Surveillance for these infectious diseases and/or the environmental conditions which promote them (high runoff with high water intake turbidity) provide examples of conditions for which indicators could be useful. In keeping with public health criteria for the appropriateness of surveillance, present enteric coliform indicators are relatively simple, specific, feasible, timely and reasonably cheap compared to the resulting public health benefits (Thacker and Berkelman, 1988).

Surveys of determinants of health, health conditions and health care utilization are another way to document health status of a population. They may be entirely questionnaire based, as in the Ontario Health Survey and the initial Canadian National Population Health Survey (Montano 1994), or they may include physical examinations and biological samples as in the U.S. — NHANES III survey (NCHS 1994). Such survey data are usually representative of the entire population and therefore can be used in a variety of ways. Primary data collection on environmental exposures is possible, as in the inclusion of a question on consumption of Alberta freshwater fish in Alberta's Heart Health survey (Elizabeth Hasselborg, personal communication). Collection of information on important confounding exposures from occupation and lifestyle has been useful for comparison with similar rates among potential high risk groups such as anglers and hunters in Ontario Areas of Concern (Deborah Jordan Simpson, personal communication). Morbidity and health professional visits reported over a specified period of time provide health outcomes of interest which have been shown to vary with local air pollution levels in Ontario (David Pengelly, personal communication).

Finally, human levels of contaminants can be ascertained (e.g. blood lead) to facilitate population attributable risk due to exposure and to demonstrate the effect of interventions to reduce exposure (e.g. removal of lead from gasoline in the U.S. and Canada resulted in declines in population levels of lead, particularly among children). The attributable risk becomes particularly important as the requirement for justification of policy and regulatory initiatives increases (e.g. virtual elimination of persistent toxic substances). It may be the best way to predict the potential of environmental exposures to produce human health effects.

Self-reported assessments of both environments and functional status or health related quality of life provide another approach to indicators which incorporates the human capacity for self reflection. A range of scales to assess physical, economic, cultural, social and institutional attributes for a variety of client populations have been summarized by Law et al. (1992). For the physical aspect, a major emphasis is on layout aspects of built environments since service providers are the major users of such scales. "Natural" environments are not separately reported. Quality of life (QOL) measures draw on literatures related to clinical outcomes and use a variety of tools (see Table XVI). A relevant example is a recently developed QOL measure for asthma patients (Juniper et al. 1992). Item subgroups include symptoms (e.g. chest tightness), emotions (e.g. concerned about having asthma), physical activities (e.g. difficulty running uphill/stairs) and environment (e.g. affected by exposure to air pollution, having to avoid dust). Asthma patients reported decreased quality of life and showed objective deterioration of lung function tests when exposed to pollution, permitting a personal assessment of impact from pollution among those most susceptible to its effects. In general populations, global self-assessments of health (Hennessey et al. 1994) can detect improvement or deterioration in well-being. Such global assessments are, however, likely to be influenced more by a host of social variables as well (Table XVII).

Considerable work has been done aggregating health data and devising indices that provide a better picture of the overall impact of the constituent conditions on the health of a population (Péron and Strohmenger, 1985). Potential years of life lost, incorporating time to death (Wilkins and Mark, 1992), and health expectancies, which also include morbidity measured by surveys and institutionalization rates (Wilkins 1992), have to date been more used for estimating the impact of social and disease factors than biophysical or environmental factors. As discussed in section IV, the World Bank (1993) has estimated environmental burden of illness using another index, disability adjusted life years, which incorporates morbidity and premature mortality. It also adjusts for severity of illness and places values on years of life at different ages. Partial monetization of the costs of such burdens has been carried out as part of the health care reform process in the United States. For example, Silbergeld (1993) focuses on costs of low birth weight and asthma and cites medical treatment and time lost costs as important levers for prevention. More systematic approaches to economic burden of illness incorporate a wide variety of direct health care and indirect costs disease groupings (Wigle et al. 1991).

Discussion of these social impacts of health status brings us to look at social indicators which are important as environmental conditions of well-being. These measures may be considered indirect results of ecosystem changes, a most striking current example being the levels of unemployment in rural Newfoundland as a result of diminished fish stocks. A similar example in the Great Lakes basin is the reduction of self-supporting status of the Akwesasne First Nation resulting from the decline of agriculture due to fluoride pollution and of fishing due to PCB contamination. Similarly but more broadly, attention has been paid to such social indicators by those wanting to monitor progress towards "healthy cities" (York University Centre for Health Studies 1990; Cappon 1991). A more recent much simplified example for use by community groups is made up of twelve core indicators, two each from production, consumption, maintenance of the physical environment, management, growth and development and social support (British Columbia Office of Health Promotion n.d.). The indicators chosen for maintenance of the physical environment were the percentage of households which reduce, reuse and recycle and whether the community water supply meets guidelines for Canadian Drinking Water Quality standards. For each indicator, notes are provided as to why it is important, what it means, measures of it, where to look for data and how to make comparisons. Such information is essential for public understanding of indicators. Similarly, a newly drafted Ontario document on guidelines to develop Community Health Profiles includes not

Table XVI. Characteristics of Measures of Health-Related Quality of Life

APPROACH	STRENGTHS	WEAKNESSES
Generic Instruments • Health Profile	• Single instrument • Detects differential effects on different aspect of health status • Comparison across interventions, conditions possible	• May not focus adequately on area of interest • May not be responsive
Utility Measurement	• Single number representing net impact on quantity and quality of life • Cost utility analysis possible	• Difficulty determining utility value • Does not allow examination of effect on different aspects of quality of life
Specific Instruments • Disease specific • Population specific • Function specific • Condition or problem specific	• Incorporates death • Clinically sensible • May be more responsive	• May not be responsive • Does not allow cross-condition comparisons • May be limited in terms of populations and interventions

Source: Guyatt et al. (1993)

Table XVII. Questions on Health-Related Quality of Life 1993 Behaviourial Risk Factor Surveillance System

1. SELF-PERCEIVED HEALTH	2. RECENT PHYSICAL HEALTH
Would you say that in general your health is? ❑ Excellent ❑ Fair, or ❑ Very Good ❑ Poor ❑ Good	Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good? __________ days
3. RECENT MENTAL HEALTH	**4. RECENT ACTIVITY LIMITATIONS**
Now thinking about your mental health, which includes stress, depression and problems with emotions, for how many days during the past 30 days was your mental health not good? __________ days	During the past 30 days, for about how many days did poor physical and mental health keep you from doing your usual activities, such as self care, work or recreation? __________ days

Source: Hennessey et al. (1994)

only health related personal practices and health status but also demographic, economic, social and physical environment indicators with a commentary on the availability of data for the indicators and the extent to which they meet pre-determined criteria (Community Health Profile Working Group, Ontario Ministry of Health 1994). Table XVIII gives a summary of the kinds of information available at most local health unit levels in Ontario (similar to U.S. states) and the wide range of determinants and outcomes being considered. The physical environment variables exemplify the heterogeneity which confronts those interested in broader approaches to health. Exposure-related ones include the number of hours of moderate to poor ambient air quality as defined by the Ontario Ministry of the Environment and Energy, frequency of poor water quality as indicated in the Drinking Water Surveillance Programme, the ultraviolet index from Environment Canada and seasonal closings of beaches from

Table XVIII. Indicators of the Community Health Profile Model

A. **Demographic**	E. **Health-Related Practices**
Population by Age by Sex Population Growth Rate Population Projections Age-Specific Fertility Rate Total Fertility Rate Ethnicity Population of Home Language Proportion of Single Parent Families Population Density Proportion of Seniors Living Alone	Proportion of Current Cigarette Smokers Proportion of Population Consuming 15 or more Alcoholic Drinks per Week Population Distribution of Binge Drinking Prevalence of Overweight Fat as Percentage of Energy Population Distribution of Physical Activity Use of Condoms as Protection of STDs Cervical Cancer Screening Breast Cancer Screening Proportion of Population Wearing Seat Belts
B. **Economic**	F. **Health Status**
Population Aged 15 and Over with Less than Nine Years of Education Proportion of Population Living Below the Low Income Cut-off Point Proportion of Social Assistance Recipients Average Employment Income Dwellings in Need of Major Repairs Percentage Owner Occupied Proportion Spending 30%+ on Housing Proportion with Subsidized Rent Number of People Receiving Food through Food Banks Unemployment Rate Cost of a Nutritious Food Basket	Life Expectancy Proportion of Live Births under 2,500 Grams Proportion of Population in Fair or Poor Perceived Health Prevalence of Selected Chronic Health Problems Leading Causes of Death Infant Mortality Rate Perinatal Mortality Rate Suicide Rate Proportion of Population Having Contemplated Suicide Motor Vehicle Injury Mortality Rate Potential Years of Life Lost Leading Causes of Hospital Separations Cancer Incidence Hospital Morbidity Due to Injury Leading Causes of Hospital Separations in Children Aged One to Nine Years Leading Causes of Hospital Length of Stay Incidence of Major Notifiable Diseases Incidence of Notifiable Diseases Requiring Vaccination Immunization Status Incidence of Occupational Injuries Dental Index Prevalence of Long Term Disability
C. **Social**	G. **Indicators Under Development**
Average Number of Persons Per Room Adult Literacy Rate Violent Crime Rate Proportion of Dysfunctional Families Voter Participation Volunteer Participation Well-Being Index Proportion of Population Dissatisfied with Their Social Life	Number of Homeless People Occupational Status Integration Index Mental Health Index Number of People in Training Programs Number of People Receiving Any Government Assistance Social Support
D. **Physical Environment**	
Number of Hours of Moderate/Poor Air Quality Frequency of Poor Water Quality Public Green Space Seasonal Closing of Beaches Ultra-violet (UV) Index	

Source: CHPWP (1994)

Table XIX: Indicators in Four Domains

Synthesis of the characteristics of indicators examined, with final 20 indicators retained highlighted in bold. Rating is 3/2/1 standing for high/medium/low or good/average/poor respectively.

Name of Indicator	Scientific basis	Frequency	Time	Geographic series	Feasibility coverage	Symbolic coverage	Synthetic (and costs) value	Total value	mean
Environment									
1. **Greenhouse gases emissions**	2	3		2	3	2	3	2	2,43
2. **Gas emissions leading to ozone layer depletion**	2	3		2	3	3	3	3	2,71
3. SOx and NOx emissions	3	3		2	2	2	3	2	2,43
4. **Major atmospheric pollutants emissions**	2	3		2	2	3	3	2	2,43
5. Air pollutant standards overstepping	3	3		2	2	2	3	2	2,43
6. **Major water pollutants emissions**	2	3		2	2	3	3	2	2,43
7. % of industrial, mining and municipal wastewaters treatment	2	3		2	2	2	2	2	2,14
8. % of water quality standards overstepping	3	3		2	2	2	2	2	2,29
9. **Total protected areas**	2	3		3	3	3	3	1	2,57
10. Total urbanized area	2	1		3	2	2	3	1	2,00
11. Number and % of endangered animals and plants species	2	2		2	3	2	3	1	2,14
12. Symbolic species: population and contamination levels	2	2		2	2	2	2	1	1,86
13. **Marine fisheries catches**	2	3		3	3	3	2	1	2,29
14. **Forest: ratio of regeneration success rate over harvest rate**	2	3		3	2	2	3	1	2,29
15. Consumption of fertilizers and chemical pesticides	2	2		3	2	2	3	2	2,29
16. Spread of degraded agriculture land	2	1		3	2	2	2	1	1,86
17. **Energy consumption per capita**	2	3		3	3	3	3	2	2,71
18. Energy production sources	2	3		3	3	3	3	1	2,57
19. **Toxic waste production (other than aquatic and atmospheric)**	2	2		2	2	2	3	2	2,14
Equity									
20. **Public aid for development and debt**	2	3		3	3	2	3	3	2,71
21. **Scholarization and illiteracy rate for children and adults**	2	2		3	3	2	3	2	2,57
22. **Distribution of personal income and property levels, by age and sex**	2	3		3	2	2	3	2	2,43
23. Women's average income as % of men's income	2	3		3	2	2	3	1	2,29
24. Regional and local parks and networks of cycle paths	3	3		3	2	2	2	2	2,43
25. **Public transport use compared to car**	2	3		2	2	2	3	3	2,43
26. **Recycling (secondary materials recovery rate)**	2	2		2	2	2	3	2	2,14
Economy									
27. **GNP per capita (adjusted for buying power)**	2	3		3	3	2	3	1	2,43
28. **Employment-to-population ratio**	2	3		3	3	3	3	1	2,57
29. **Military expenditures in relation to other govern. expenditures**	2	3		3	3	2	3	3	2,57
30. Satellite accounts	N.A.	N.A.		N.A.	N.A.	2	3	2	N.A.
31. Resources accounts	N.A.	N.A.		N.A.	N.A.	2	3	2	N.A.
Health									
32. **Obesity (adults) and malnutrition (children) proportions**	3	2		2	3	3	3	2	2,5
33. Caloric intake, and proportions from vegetable and animal sources	**2**	**2**		**2**	**2**	**3**	**2**	**2**	**2,14**
34. **Health expectancy**	**2**	**1**		**2**	**1**	**1**	**3**	**2**	**1,71**
35. Life expectancy at birth	**3**	**3**		**3**	**3**	**3**	**3**	**2**	**2,86**
36. **Preventable deaths**	2	3		3	3	3	2	2	2,57
37. Human development index	2	3		3	3	3	1	2	2,43
38. Deaths by violence	1	3		3	3	1	3	1	2,14
39. Low birthweight	3	3		3	3	3	2	1	2,57

Source: Gosselin et al. (1993)

local municipalities. The amount of public green space is also included. Although it is a planning criterion without clear direct health effects, it does connect to ecosystem and sustainability, our next section.

We can summarize: the best measures to monitor the potential of environmental exposures to produce human health effects are the actual monitoring of the agents that are known to produce an effect at low levels of exposure through air and water. A case can be made for creating a database monitoring persistent organochlorines in the population, but this recommendation may be influenced by the outcomes of current ATSDR funded studies of PCBs and neurobehavioural effects. New research on the endocrine modulators is needed. Until there is a much clearer understanding of the effects of these chemicals, better characterization of human exposure to them, (serum total PCBs likely being a cost effective and representative measure) is warranted. In terms of effects of toxic agents in the environment on the health of humans in the Great Lakes region, hospital admissions for children under one year of age for asthma/respiratory disease is the most clearly defensible indicator at this time.

Sustainability Indicators

Environmental, human health, social status and economic indicators are all deemed relevant in the burgeoning literature on "sustainability." At the international level this is often linked to human development in general as in the United Nations "Human Development Index," a nationally based composite of a wide range of routinely collected data on many aspects of society (UNDP 1994). An internationally coordinated endeavour furthered by OECD countries pared down the list to include indicators in each of four main areas: environment, equity, economy and health (Gosselin et al. 1993). Those indicators highlighted in Table XIX include ones that might be useful for comparison purposes (e.g. major water pollutants emissions), ones that would likely not be sensitive enough for monitoring environmental burden of illness impacts (e.g. life expectancy at birth) and ones that are not applicable in the Great Lakes basin (e.g. marine fisheries catches or public aid for development or debt). Canadian work by the National Roundtable of Environment and Economy (1993) on sustainable development proposed a partial list of rudimentary indicators (Table XX). Yet they sub-title the People Indicators (Human Well-Being) section "An Interdisciplinary Morass." They elaborate:

> *To monitor and assess the human dimension of sustainable development, insights must be drawn from a large number of disciplines. But the turf of these disciplines often lies protected by broad moats and high walls founded on language and concepts that only the initiated can fathom.*

They go on to describe a range of initiatives aimed at unifying the health information systems in Canada. Wolfson (1994) has described one approach to such a synthesis which might be worth building on for the ecosystem-human health relationship. He argues for a System of Health Statistics, rather like the System of National Accounts. His proposed template groups data into one of three main domains: individual characteristics, the external milieu and health-affecting interventions at both the individual and collective levels. The external milieu includes physio-chemical environments, sociocultural environments, economic environments and health system environments, all described longitudinally over time. Health affecting interventions at the collective level might include reduction of air and water pollutant emissions. Disaggregation of each of the subdomains is important. Thus within the physiochemical environment subdomain, information might be classified according to the medium by which people are exposed (e.g. air, water, food), by the place or microenvironment where they are exposed (e.g. home, school, workplace) or the agent to which they are exposed (e.g. inorganic compounds, microorganisms, persistent organochlorines) (Andrews and Newsome, 1994; Furst et al. 1994). Such an approach would demand a much greater interest in systematic exposure documentation across populations than presently occurs in order for sensible linkages to be made with other domains and subdomains. An approach operating at distinct levels of a hierarchy would however permit the inclusion of regionally based data and incorporation of data collected during focused surveys of populations at high risk for particular health outcomes (e.g. angler or immigrant fish consumers).

At the provincial level, the Ontario Round Table on Environment and Economy has taken the lead in developing an environmental information policy, based on an expert workshop, (Institute for Research on Environment and Economy 1992) and a framework for reporting on sustainability (Hodge and Taggart, 1992). The former document discussed a number of the issues and challenges in environmental information and some measures for optimizing information systems. Of particular interest is a comment on data selection: "Over time, data series which

Table XX: Reporting on Sustainable Development

Box 2 A Partial List of Rudimentary Indicators

I. ECOSYSTEM

- temperature (daily and trends over time)
- concentrations of contaminants in indoor and outdoor air that are: common (CO_2, NO_2, ground-level ozone, carbon monoxide); and toxic (dioxins, lead, etc.)
- concentrations of contaminants in water (mercury, DDT, PCBs, etc.)
- concentrations of contaminants in the tissue of fish, birds, wildlife, and humans (lead, PCBs, DDT, etc.)
- rates of soil erosion
- acid deposition
- loss of wildlife habitat
- the state of biodiversity:
  - genetic (diversity within species), and
  - species (diversity in the number of distinct species)
- species health (births, survival rates, deformities, etc.)
- population shifts of wildlife (eagles, caribou, counts of migrating salmon in the Fraser River, etc.)

II. INTERACTION

- contribution to well-being by activity (value-added by: agriculture, manufacturing, financial services, housework, etc.)
- resource use (per unit of time, or per unit of output)
- generation of contaminant emissions:
  - heat and waste products per capita, or per unit of production
  - loadings to air, surface water, groundwater, or land by activity (by automobiles, pulp and paper manufacturing, energy production, etc.), and
  - the totals for regions and the nation
- proportion of materials recycled
- renewable resource harvest rates
- non-renewable resource extraction rates
- degree of compliance with laws and regulations

III. PEOPLE

- infant mortality rates
- literacy rates
- life expectancy at birth
- incidence of disease
- employment and unemployment rates
- income levels
- degree of pride in community and culture
- corporate bankruptcies
- level of indebtedness (individual, community, and nation)
- obesity (adults)
- malnutrition (children)
- caloric intake, and the proportion of it acquired from local, Canadian, and foreign foods

National Round Table (1993)

Table XXI: A Draft Goal Statement for an Ontario System of Reporting on Sustainability

I. SYSTEM CHARACTERISTICS.

To develop systematic reporting on sustainability as a means of assessing progress towards Ontario development goals based on:

1. Values
- recognition of the range of values held by Ontario residents;
- recognition that values are dynamic and will change over time;

2. Time Horizon
- a time horizon that captures both human short-term (social, political, economic and intergenerational) and long-term (ecosystem) dimensions of time;

3. Spatial Perspectives
- a regional spatial perspective that focuses on Ontario but recognizes regional, national, and international transboundary ecosystem linkages;

4. Equity and Social Justice
- a commitment to assessing equity and social justice;

5. Empowerment
- a commitment to assessing individual and community empowerment as reflected in participation and control in decision-making;

6. Uncertainty
- recognition and explicit description of uncertainty;

7. Anticipatory Perspective
- recognition of the need to assume an anticipatory perspective with both the form of chosen indicators and a time-horizon of analysis that allows forward looking applications, not just description of past and current conditions;

8. Non-market and Market Activities
- recognition of both non-market and market human activities;

9. Range of Environmental Stresses
- recognition of the complete range of physical, chemical, and biological stresses imposed by human activities on the environment;

10. Knowledge Base of Both "Hard" Numbers and "Soft" Experience
- recognition of the need to draw on both "hard" data and information as well as from "soft" intuitive understanding such as knowledge gained from experience of subsistence and traditional life styles;

11. Integrated System of Indicators of Sustainability
- an integrated system of indicators of sustainability that allows monitoring and assessment of constituent parts but only within a respect for and continual reference to the whole.

12. Assessment
- a willingness to periodically assess and draw conclusions in light of the best available knowledge base, part of which will be "hard" data and information and part of which will be "soft" intuitive understanding;
- a commitment to clearly record the rationale for any assessments thus providing the needed base for maximizing the growth in understanding of complex systems over time.

II. SUPPORT FOR POLICY AND DECISION-MAKING.

To facilitate reporting in support of improved policy and decision-making in Ontario at four levels:
- individual — residential;
- establishment — sector;
- community — settlement; and
- region — province.

III. ENVIRONMENTAL STRESS REDUCTION.

To provide a reporting system aimed at identification of the most effective path for reduction of stress imposed on the ecosystem by human activity.

IV. COST EFFECTIVENESS.

To maximize the cost-effectiveness of the reporting system by facilitating partnerships between and within the private and public sectors.

V. INSTITUTIONAL MEMORY.

To maximize the opportunity for permanently recording relevant data, information, and experience.

VI. LINKS TO OTHER INITIATIVES.

To maximize coordination with other related reporting initiatives including those of the Government of Canada, adjacent jurisdictions, industry, and non-governmental organizations and in particular, with efforts directed towards settlement of aboriginal land claims.

Source: Hodge & Taggart (1992)

Table XXII. Sample Indicator Categories

SOURCE	SUGGESTED INDICATOR CATEGORIES			
Council of Great Lakes Research Managers (1991)	**Compliance** — monitor the attainment and maintenance of ecosystem objectives	**Diagnostic** — provide insight as to the cause of noncompliance	**Early Warning** — anticipate changes of interest before substantial impact has occurred	
Rapport and Davies (1992)	**General Screening** — determine, at a broad scale, whether or not an ecosystem is healthy	**Diagnostic** — identify specific causes of ecosystem degradation	**Risk Factors** —reflect stresses and/or potential hazards which may not yet be realized or reflected in the ecosystem data	**Fitness** — measure an ecosystem's capability to respond to stress (no current examples)
Environment Canada, Indicators Task Force (1991b)	**Conditions/Trends** — measure current states of environmental components	**Causes and Stresses** — measure human activities which affect environmental components	**Management Responses** — measure management effective ness with respect to different environmental components	
Organization for Economic Cooperation and Development (1991)	**Pressures** — measure stresses on the environment, (i.e. pollutants)	**State** — measure the state of the environment and natural resources	**Responses** — measure the effects of stresses on the environment	
Kelly and Harwell (1989)	**Early Warning** — rapid detection of potential effect	**Sensitive** — reliability in predicting actual response	**Intrinsic Importance** — an indicator species is itself the ecological endpoint of concern	**Process/ Functional** — the desired endpoint is a process
Knapp et al. U.S. EPA (1991)	**Exposure** — provide evidence of the occurrence or magnitude of contact of an ecological resource with a physical, chemical, or biological stressor	**Stressor** — effect changes in exposure and habitat	**Response** — provide evidence of the biological condition of a resource at the organism, population, community, ecosystem, or landscape level of organization	**Habitat** — characterize conditions necessary to support an organism, population, community, or ecosystem
Cairns (1992)	**Species** - *structural* — e.g. tissue or organ damage *functional* — respiratory rates or behaviour	**Community** - *structural* — trophic relationship *functional* — colonization rate or rate of detritus processing	**Ecosystem** - *structural* — trophic relationships characteristic of this particular ecosystem type in this locale *functional* — nutrient spiralling or energy cycling	**Landscape** - *structural* — compatible with the landscape mosaic *functional* — landscape used with appropriate duration and frequency by species that regularly use the larger mosaic of which this is a part

Source: CCME (1994)

Table XXIII. Ecosystem Health Indicator Selection Criteria Developed by the Council of Great Lakes Research Managers

Biologically relevant	...i.e. important in maintaining a balanced biological community
Socially relevant	...i.e. of obvious value to and observable by shareholders or predictive of a measure that is
Sensitive	...to stressors without an all-or-none response or extreme natural variability
Broadly applicable	...to many stressors and sites
Diagnostic	...of the particular stressor causing the problem
Measurable	...i.e. capable of being operationally defined and measured, using a standard procedure with documented performance and low measurement error
Interpretable	...i.e. capable of distinguishing acceptable from unacceptable conditions in a scientifically and legally defensible way
Cost-effective	...i.e. inexpensive to measure, providing the maximum amount of information per unit effort
Integrative	...i.e. summarizing information from many unmeasured indicators, one for which
Historical data is available	...to define nominative variability, trends and possibly acceptable and unacceptable conditions
Anticipatory	...i.e. capable of providing an indication of degradation before serious harm has occurred, early warning
Nondestructive	...of the ecosystem, one with potential for
Continuity	...in measurement over time, of an
Appropriate scale	...for the management problem being addressed. For the International Joint Commission, there are three relevant spatial scales: the Area of Concern, Lakewide management and the basin ecosystem and many appropriate temporal scales
Not redundant with other measured indicators	...i.e. providing unique information
Timely	...i.e. providing information quickly enough to initiate effective management action before unacceptable damage has occurred.

Source: IJC (1991)

are gathered to describe and monitor particular problems become unnecessary as the problems are resolved. Review mechanisms for assessing data utility do not exist. As a result, data gathering exercises tend to continue, regardless of usefulness." Such a dilemma is apparent in the Great Lakes basin where the extensive animal and fish biomonitoring data on contaminant levels exist but similar human information is scarce. One suggestion in the report is that in each of the next five years, 10 percent of the environmentally-related data sets should be either discontinued or re-cast to make them relevant to sustainability, human health, equity. Hodge and Taggart suggest a draft goal statement for an Ontario system for reporting on sustainability (see Table XXI). Part I on system characteristics suggests a broad range of considerations of both a technical (e.g. spatial scales) and a social (e.g. values and equity) nature. Particularly interesting is the emphasis on "soft" experience which may either temporarily substitute for or considerably enrich the usual quantitative information on which state of environment reports and health statistics so heavily rely. At the municipal level, considerable energy is also going into the development of indicators of sustainability. Some question their value (Brugman 1994):

> *Indicators are highly academic exercises which can easily obfuscate political expediencies and status quo values.... For example, indicators of air quality do not reliably indicate equity in the distribution of clean air between middle class and poor residents of a city.*
>
> *They do not reliably reveal what actions are causing a change in air quality. They do not often reveal whether reductions in one air contaminant are related to increases in other pollutants (in other media). And they cannot estimate future trends. These key elements of sustainable development - equity, integration and longevity - cannot be measured using a traditional indicator approach. ...but he also offers some guidance in their use:*
>
> *What we can say is that, just as when applied to regulations, indicators can be effectively used to measure and influence progress in implementing action strategies which may result in a more sustainable situation (note the uncertainty). An indicator can reveal whether people, organizations or governments are taking desirable (or undesirable) action....*

Criteria for Indicators

Desirable characteristics of indicators have been dealt with in a variety of ways in different literatures. Oftentimes, and as in the bulk of this section, categories of indicators are developed to ensure a variety of goals. Thus, CCME (1994) bring together a series of different types of indicators which have served to monitor broadly defined ecosystem health (Table XXII). But in such categorizations many important outcomes mesh together. Clarity of purpose is lost. Thus it becomes important to set out criteria for indicator selection. One of the simplest (Rapport and Friend 1979) has already been suggested. More complexly, IJC (1991) set out sixteen desired criteria for selecting suitable indicators (Table XXIII). It is recognized that no single indicator is likely to meet all the criteria. In fact, the IJC (1994) in its bioindicators report as a measure of success for the virtual elimination of persistent toxic substances suggests four criteria: specificity to the substances, placement in appropriate scales, costs of measurement and social relevance/public perception. This is a sensible list. We also suggest a simplified but more generic approach to indicator criteria, there being a two-fold division — science-based and use-based, always remembering from section II that all indicators are goal-directed and that good indicator selection is dependent on specifying the problem to be measured and managed. Data availability and quality then become key. In fact, as we have seen, many ecosystem and health information discussions take up scientific issues in data quality. For example, the Community Health Profile document (1994) examine health data integrity (e.g. completion of records, nature of sampling in brief surveys), geographic coding issues (e.g. postal codes vs. census subdivisions), confidentiality and data access, and data gaps. It also recognized that as communities attempt to use data from a range of other governmental and institutional sources, differential attention to data quality, updating, and structure may make integration a difficult process. These and other scientific issues have also been reviewed in the context of social statistics (Eyles 1994). They are generic to a discussion of the scientific quality of indicators and constitute the first set of criteria:

- data availability and suitability — it is likely because of cost constraints that existing data-sets have to be used in the construction of social indicators. It is further likely that those data were collected for different purposes than now required. For example data may provide activity records of particular departments, institutions and personnel. Further, census data on demographic and socio-economic characteristics of populations census is important as custom-made surveys may be one-offs or may be repeated at regular intervals with different questions or areas of interest, e.g. the Canadian Social Survey. But indicators can be constructed only if data are available.

- indicator validity and reliability — to be valid, an indicator must measure the phenomenon or concepts it is intended to. There are four types of validity:
  - face validity (after evaluating the rationale behind indicator selection, is it a reasonable measure?)
  - construct validity (does the measure behave as expected in relation to other variables in a model of the segment of the social world?)
  - predictive validity (does the measure correctly predict a situation which would be caused by the phenomenon being measured?)
  - convergent validity (do several measures collected or structured in different ways all move similarly over time?).

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  - predictive validity (does the measure correctly predict a situation which would be caused by the phenomenon being measured?)
  - convergent validity (do several measures collected or structured in different ways all move similarly over time?).

These validity checks should be carried out jointly and become especially important when indirect indicators have to be employed. Reliability depends on the amount of error variance in the measurement of an indicator. Reliability is determined by repeatability, by carrying out repeat measures using the same indicators. It is possible though that the object being measured changes so a new phenomenon is being examined in any retest. In using indicators, it is necessary to be aware of extraneous factors that may influence measurement. Some are easy to discern, such as the changing basis of collection of some types of statistical data. Some are less easy to notice. What is the effect of the time of day or day of the week when a measurement was taken? What is the effect on the variable of interest of changing life circumstances and attitudes? These concerns may affect self-reports rather than quantitative measurements, although Bateson's (1972) and Allen and Hoekstra's (1992) admonitions (see section II) must be remembered.

- indicator representativeness — questions of data representativeness are quite easy to recognize, based as they are on sampling procedures and size and population characteristics. More troublesome is the issue of indicator representativeness. Is it possible to select one or several indicators that cover important dimensions of concern? Birch and Eyles (1991) use the standardized mortality rate as a single, indirect indicator of premature mortality and hence health status in Ontario. Although open to debate on indicator suitability, the use of a single indicator does have the advantage of making comparisons between groups and areas and over time comparatively easy. Indicator representativeness may be enhanced by developing an index. Even if the problems of combining indicators can be overcome, there remains the problem that if the index rises or falls, it remains unknown if all its constituent indicators are rising or falling or remaining the same. Or the pattern of changing values may be mixed. Indices may be then of limited value.

- indicators as comparators — not only must data be available for several time periods, they must also mean roughly the same thing at those times. But the sensitivity of measurement procedures may change as may the nature of the population being surveyed. The "new" population may have different preferences or cultural practices, number of sole parent families, restrictions on age of and partner for marriage or different susceptibilities to disease which may affect indicator values. These may also be affected if what is being measured is seen differently, e.g. what constitutes disability, mental illness, or disease. A different type of comparison concerns that between-groups. What is being measured must be meaningful in similar ways to all groups. Early on, Townsend (1954; 1979) was critical of how official poverty standards (such as those in Canada, Britain and the U.S.) are constructed as they fail to take into account how poor people actually spend their money. This work has had virtually no impact. The standards are still based on rational expenditures to meet basic needs including minimum nutritional levels. Similarly, background exposures must be similar if we wish to compare the exposure histories in two different populations.

- desegregating indicators — to be informative, indicators must be able to be related to other variables. If an indicator can be broken down by many variables, it tells us a great deal more. The OECD (1976)

identifies three types of disaggregation:
- by ascribed characteristics, e.g. age, sex, race, region
- by well-being characteristics, e.g. years of education, family income, employment status, family status
- by contextual characteristics, e.g. size of community, type of occupation, level of social support, cause of death.

Although disaggregation is important, it can bring additional problems, particularly if we disaggregate to lower-level geographical scales. What makes sense as a cross-national comparison, e.g. literacy rates, may make less sense in terms of interprovincial comparisons in Canada or between Ontario and New York State. Further, the same indicator can produce very different pictures of well-being or deprivation depending not only on the geographical scale adopted but also on the spatial units used.

What are the use-based criteria for indicator selection? Let us repeat that as much clarity as is possible is required with respect to the relationship between the indicator and the goal (purpose, use, state) that it is meant to monitor. There are then some practical use-related criteria, namely:

- feasibility — are the data already collected? If they are, are they available for the right time-periods and at the desired geographical scale? If they are not, how feasible is it to create surrogate or indirect indicators of the phenomenon of interest? If this is carried out, what happens to scientific validity? Further if the data are not collected, how expensive would it be to alter the information-gathering system? The answer to this question involves not only the dollar-cost but a trade-off between these costs and potential benefits. Those benefits may in turn be measured by desirability.

- desirability — do the indicators inform on the state of the environment or of health in ways that are perceived as important by those affected by that being measured? Do the indicators enable residents of a particular region or the members of a particular population group to assess their needs and risks? Do the indicators enable them to make meaningful comparisons with similar groups of residents or population members? A feature of desirability is in fact credibility (a user-version of validity). Does the indicator have credibility in the sense that it measures something important to us and our neighbours and region? Let us note that desirability/credibility are dependent upon the core-values and the relative significance of life-domains, discussed in section III.

- gameability — if there is to be a link between public perceptions and indicators, then we must ensure that indicators are not gameable, i.e. that they cannot be "gamed" or altered by those with something to gain (while others lose) from the indicator being pushed in a certain direction at a particular pace. If, for example, the distribution of health care resources is dependent on level of self-reported health status, then it is advantageous not to report gains in status. Further, if resources for improvements in water quality are dependent upon a particular level of microorganisms, it may pay a municipality to defer reporting improvements until budgetary allocations are made. While gameable behaviour is often unethical and therefore unlikely to be pursued by health or ecosystem monitors, a surveillance system may be required or an appropriate reward-system derived to prohibit "gaming."

- manageability — the ability of human beings to process information is limited. Miller (1956) has argued that the "magic number" for such processing is seven plus or minus two. If that is the case, we must ensure that we select a limited number of indicators. How then do we decide on which 7 ± 2? It must partly be on the basis of desirability and feasibility but two other criteria suggest themselves.

- balance — we must ensure, if appropriately specified in our goals, that there is a rough balance among all of the phenomena of interest. For example, in developing its indicators of sustainability, the Regional Municipality of Hamilton-Wentworth is trying to balance the concerns of economy, environment and health/society. For the purposes of this monograph, where we have indicated the equivalent importance of ecosystem health and human health, we would see the need for three sets. Within the ecosystem one, there would be the flora and fauna concerns and the quality of media such as air and water. Within human health there would be key measures of environmental conditions for well-being, potentially related health outcomes (e.g. asthma admissions) and quality of life measures. The third group-linkages between the ecosystem and human health — requires most developments. At the initial stage, based on this criterion, we are suggesting no more than between 15 and 27 ($7 \pm 2 \times 3$) indicators.

- catalyst for action — we may choose to distinguish indicators that more or less act as catalysts for action whether that is on the part of industry, government, communities or individuals. This criterion is important in another way in that it relates indicators firmly to the goals of monitoring.

In sum, we have identified two sets of criteria for indicator selection. The first is scientific:

- data availability and suitability
- indicator validity and reliability
- indicator representativeness
- comparability of indicators
- disaggregation of indicators.

The second is use-related:
- goal-defined and oriented
- feasibility
- desirability/credibility
- gameability
- manageability
- balance
- catalyst for action.

We recognize that this represents a long list of criteria (twelve) but some merely constrain selection at all times e.g. data availability, goal orientation, manageability, balance and even catalyst for action (related as it is to goals). But they do require stating. These criteria then serve a dual purpose, acting as criteria for the suitability of indicators per se and then as criteria for specific indicator selection. Further, they enable those concerned with monitoring ecosystem health and human health in the Great Lakes basin to consider together matters of proof (primarily but not exclusively the scientific list) and of prudence (primarily but not exclusively the use list).

Concluding Remarks

As can be seen, writers from environmental backgrounds have been expanding ecosystem health to incorporate human health and social indicators as indirect outcomes of ecosystem functioning. Similarly writers from health and social science backgrounds have moved from morbidity, mortality and disability measures to community wide measures that incorporate environmental and social determinants and measures of health. Each tends towards less depth and concern about the measurement properties of those indicators outside their traditional expertise with resulting neglect of some important measurement issues. As typified by the indicators suggested for sustainability, all measures of human activity may ultimately result in both ecosystem and human health effects and human health and social measures are affected by ecosystem integrity because of impact on the sustaining web. All writers seem to be aware, although not always explicitly, of measurement, aggregation and interpretation issues in the use of indicators. Hence, we advocate the use of criteria for indicator suitability and selection, taking into account the tension that is present in bringing together ecosystem health and human health.

VI.

RECOMMENDATIONS

In this monograph, we have provided some discussion of the issues surrounding the definition and measurement of ecosystem health. We have briefly examined the relationship between human activity and ecosystem health before moving to the main sections of this report, namely exploring the implications of inserting "human health" in "ecosystem health" through consideration of definitions and metaphor, the environmental burden of illness and the environmental conditions for well-being. We then identify indicators of human health and ecosystem health, briefly outlining those pertaining to the environment, human health, and sustainability. We conclude by putting forward science — and use-oriented criteria for indicator suitability and selection. In this final section, we isolate key recommendations that have emerged in the course of this discussion. We begin by pointing to the most specific, concluding with those that are, in scientific terms, more general. We therefore put forward for consideration:

- continued monitoring of toxins in media, including: trihalomethanes, nitrates, microbial contaminants in drinking water; PM-10, ozone and sulphates in air; and persistent organochlorines in fauna.

- systematic synthesis of results of water sampling for microbial contaminants which result in beach closings. Consider complementing these with information on symptoms among beach users.

- inclusion of relevant ambient exposure factors (e.g. time outdoors based on activity record) and consumption factors (e.g. freshwater fish and wildlife) in population based health surveys. General population based measures of body fluid levels of key contaminants (e.g. PCBs or DDE for the organochlorines in serum and breast milk, mercury and lead in whole blood for the metals) could be linked with these and other relevant social factors.

- surveillance of established environmental health outcomes, such as asthma, such that these conditions may be considered as sentinels for pollution effects.

- recognition that some human illness indicators are poorly suited to provide useful information on the impact of environmental exposures on human health, e.g. much currently routinely collected morbidity and mortality data including rates of cancer.

- development of longitudinal designs around exposures and conditions of interest to enable stronger inferences concerning relations between exposure and health outcome to be made.

- identification of appropriate human health, well-being and quality of life (QOL) indicators in assessments of the impact of environment on humans. While some of these will be specific to the environmental burden of illness, evaluations remain to be made concerning the appropriateness of some of the health-related QOL measures. We argue that a systematic review of QOL indicators from a range of literatures be undertaken to assist in the development of appropriate health and well-being measures of Great Lakes populations.

- support for the development of indicators and scales that measure the environmental component of illness and well-being, potentially in the form of an index of environmental distress which must be sensitive enough to allow for separate components of interpersonal health and stress and robust enough to be of general value, i.e. not merely event-driven.

- recognition of the need to separate indicators of ecosystem health and human health as their goals and targets are so different, in the former case ecosystem stability, persistence or resilience, in the latter the disease or illness state of individuals and human populations.

- monitoring of state of the environment and sustainable development reporting. As these reports often take a broad-based approach to indicator selection, this monitoring is necessary to help ensure the integration of human exposure into data-base assessments on relevant species (fish and wildlife) contamination.

- recognition that all indicators are goal-directed, that they essentially monitor "system" change given desired outcomes. All indicators (as they are selected from an unknowable universe of all possible indicators) are normative.

- identification of "ecosystem" and/or "environment" as a core-value of interest in the identity-formation and concerns of populations in the Great Lakes basin.

- clarification of the value-sets that determine indicator selection for ecosystem health and human-health indicators.

- recognition that "ecosystem," "health consequences" and so on are abstracted notions, with implications not only for what we measure but how we measure things. The notions that become powerful, that have resonance, take on metaphorical significance-hence the need for value clarification.

- given the above issues, establishment of criteria for determining indicator suitability and selection. We recommend the use of two broadly-defined sets of criteria: one scientific, the other use-oriented. Thus a good environmental health status indicator is not only goal-directed, monitoring change at an appropriate time scale at an appropriate geographic scale, it also ensures consideration of data availability and suitability, validity and reliability, representativeness, comparability and the need for disaggregation as well as feasibility, desirability, gameability, manageability, balance and catalyst for action. The scientific criteria emphasize the burden of proof, the use-orientated criteria the need for prudence.

- recognition that adoption of a prudent or precautionary stance towards the evidence of health effects must be open to scientific evidence. We support the attention being given to decision-rules to evaluate claims to precaution. These rules are likely to be a mix of the scientific and use-oriented criteria also employed for indicator selection.

- caution concerning the connectionist view of the world. While we concur with the connectionist, network approach to human health-in-relation-to-ecosystem, we argue that its utility is as a framework — an overarching recognition which warns of possible trade-offs, side-effects, possible unintended consequences and unanticipated events. It should not be so overarching that it limits capacities to act in sub-systems or among sub-populations. It may be necessary to see things in functional terms, in terms of the looseness or tightness of fit between parts, of coupling. In this, we must battle the power of metaphor.

LIST OF ACRONYMS

ACES	Advisory Committee on Environmental Standards
ATSDR	Agency for Toxic Substances and Disease Registry
Bq/L	Becquerels/litre
CAT (scan)	Computerized axial tomography (scan)
CCME	Canadian Council of Ministers of the Environment
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
CPHA	Canadian Public Health Association
DALY(s)	Disability adjusted life year(s)
DDT	Dichlorodiphenyltrichloroethane
DNA	Deoxyribonucleic acid (Double helix of DNA which contains the genetic code)
EHIA	Environmental health impact assessment
GIS	Geographical information system
GLHEP	Great Lakes Health Effects Program
GLSAB	Great Lakes Science Advisory Board (International Joint Commission)
GNP	Gross national profit
HFA	Health For All
IARC	International Agency for Research on Cancer
ICD	International Classification of Diseases
IJC	International Joint Commission
ITFM	Intergovernmental Task Force on Monitoring Water Quality
me/L	miliequivalents per litre
MOEE	Ontario Ministry of Environment and Energy
NCHS	National Centre for Health Statistics
NHANES	National Health and Nutrition Examination Survey
OECD	Organization for Economic Cooperation and Development
P	Probability
PAH(s)	Polynuclear aromatic hydrocarbon(s)
PCB(s)	Polychlorinated biphenyl(s)
PM-10	Particulate matter of 10 microns or less
QOL	Quality of life
RAP(s)	Remedial Action Plan(s)
RR	Relative risk
SAB	Science Advisory Board
SOE	State of the environment
SO_x	Sulphur oxides
TCDD	Tetrachlorodibenzo-*p*-dioxin (dioxin)
U.S. EPA	United States Environmental Protection Agency
UNCED	United Nations Conference on Environment and Development
WHO	World Health Organization

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