CANADA'S NATIONAL ENVIRONMENTAL INDICATORS PROJECT

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Introduction

Environmental indicators are tools for translating and delivering concise, scientifically credible, environmental information in a manner that can be readily understood and used by decision-makers and the general public. We are in the habit of using economic indicators, developed over the past 30 years to measure the state of the economy, but we have had few indicators that could give us a similar snapshot of the state of the environment. This situation is now changing: numerous international organizations and national agencies are devoting research and development efforts to the elaboration of environmental indicators.

An indicator is a statistic that, measured over time, provides information on trends in the condition of a phenomenon and has significance extending beyond that associated with the properties of the statistic itself. *Environmental indicators* are selected key statistics which represent or summarize some aspect of the state of the environment, natural resource assets and related human activities. They focus on *trends* in environmental changes, stresses causing them, how the ecosystem and its components are responding to these changes, and societal responses to them.

In Canada, environmental indicator work proceeded intermittently between the early 1970s and the late 1980s. Inhaber (1972) and colleagues, for example, attempted to develop a single national environmental index for Canada. At the time, Inhaber's methodology was deemed too complex, the variables and supporting data insufficient and the results ultimately too simplistic to be meaningful; the project was abandoned. During the intervening years, despite the perceived technical difficulties with the development of environmental indicators, the concept kept resurfacing as decisions continued to be made in the absence of adequate signals concerning the state of the environment.

Environment Canada's newly created State of the Environment (SOE) Reporting Organization resumed work on indicator development in 1988. But the real impetus for this pursuit came in 1989 when the Group of Seven Economic leaders, at their Paris Summit, requested the OECD to develop environmental indicators in the context of improved environment-economic decision-making. The Canadian Prime Minister was instrumental in placing indicators on the G-7 agenda, and Canada took up the challenge.

A number of agencies and groups in Canada, both government and non-government, are currently engaged in environmental indicator development and related areas. At the national level, Statistics Canada, for example, is completing oil and gas and forest pilot projects under a natural resource accounting initiative. Forestry Canada has developed an initial set of forestry performance indicators that can be used to describe and evaluate environmental, social and economic values of the Canadian forest resource. And Agriculture and Agri-Food Canada is in the process of defining a set of agri-environmental indicators.

Environmental indicators are recognized in Canada's Green Plan as an important tool of state of the environment reporting. These indicators, regularly monitored and reported, will provide a 'common currency' by which to track trends in the state of the environment and progress towards the environmental goals of sustainable development.

Under the Green Plan, the federal government made a commitment to develop a preliminary national set of environmental indicators by mid-1991 and initiate stakeholder consultations on it. Further, the plan committed the government to develop and report regularly on a comprehensive set of environmental indicators beginning in 1993. This work is proceeding under the National Environmental Indicators Project, a federal initiative led by Environment Canada's SOE Reporting Organization and the focus of this paper.

National Environmental Indicators Project: Phase I

The objective of this project is to develop scientifically credible, understandable, environmental indicators relevant to decision-makers and the public, and to report regularly on them. The set of indicators should reflect in a synoptic way the state of Canada's environment and indicate trends towards the environmental goals of sustainable development. Ideally, the set should be small and yet of sufficient breadth to capture the major environmental concerns. It was recognized at the outset that indicator development is a long-term process and that it would take some years before a definitive set of indicators would be agreed upon, accepted and used.

Before launching full-scale into this Indicators project, two studies were conducted in the Fall of 1989 to determine the feasibility and usefulness of developing a national set of environmental indicators. Environment Canada and Statistics Canada, working with a small group of specialists, assured the technical feasibility and outlined a preliminary framework and method of selecting indicators for a national set of environmental indicators. In addition, fifty-one opinion leaders from across Canada -- environmentalists, health specialists, representatives from industry, native groups, the media, universities and federal and provincial governments -- provided their views on the usefulness of, and preferences for, environmental indicators. An Indicators Task Force in Environment Canada was established in February 1990, to develop an initial national set of environmental indicators, in collaboration with other federal agencies.

Strategy

Developing a preliminary national set of environmental indicators required a strategy and framework to give the process some structure and limits. A number of steps to guide the selection and development of indicators were elaborated:

- identification of societal goals to which indicators would relate;
- development of a framework within which indicators could be identified;

- identification of criteria for selecting environmental indicators;
- consultation with specialists, data holders, and potential users;
- verification that indicators are effectively communicating environmental information to the intended audiences.

Conceptual Framework

The development of a framework for indicators was guided by three societal goals related to environmentally sustainable development:

- to assure the viability of ecosystems;
- to assure the protection and enhancement of human health and well-being; and
- to assure the protection, maintenance and sustainability of natural resources.

A number of approaches were examined in pursuit of a conceptual framework that would guide the systematic and comprehensive identification of appropriate environmental indicators. In an "issues" framework, specific environmental problems are identified and analyzed, but may change over time; an "environmental media" organization covers the basic environmental components of air, water, land and biota, but doesn't convey the integrated nature of environmental components; a "resource sector" framework divides the environment into sectors according to its usefulness and relationship to economic activities. In an "ecosystem" approach, information is presented for geographical units that contain distinctive sets of abiotic and biotic features that are ecologically interrelated (Sheehy, 1989a; VHB Research and Consulting Inc., 1989). The "environmental processes: or STRESS framework organizes environmental information according to stresses placed on the environment by human activities and natural events; environmental conditions or responses reflecting changes in state of physical and biological components of the natural system; and human responses or actions taken to modify environmental stresses and responses (Statistics Canada, 1989). Each framework views the environment from a slightly different angle, each with its own merits. In order to cover the breadth of the environment comprehensively, a combination of these approaches was employed to devise the conceptual framework for the indicators project. Several iterations of a matrix were developed in an attempt to translate the conceptual to the practical (Kerr, 1991).

The initial matrix consisted of, on the vertical axis, three broad categories namely, environmental components, environment-related human health, and natural economic resources that reflected the environmental goals of ecosystem viability, human health and well-being, and natural resource sustainability. Within each of these categories, environmental *issues* were identified. These issues were selected after widespread consultations with specialists and interested stakeholders within and external to government, extensive analysis of journals, news clippings and opinion polls related to the environment, and on the basis of global and national concerns, Canada's Green Plan priorities, and

Department of the Environment priorities. Issues are those of long-standing importance and not the "here-today, gone-tomorrow" variety. The types of indicators to be selected were identified through the STRESS framework. Thus three categories traditionally used to report trends in the state of environment, i.e. conditions/state of the environment; causes and stresses; and management responses, made up the headings on the horizontal axis of the matrix. The intent of the matrix was to identify indicators of change that reflected the dynamic nature of environmental processes in each of the broad categories on the vertical axis. (See Figures 1 and 2.)

Conceptually, the matrix helped to identify indicators systematically. However, it soon became clear that overlaps resulted because of the interconnected nature of the environment itself and human interactions with it. For example, water is an essential environmental component for ecosystem viability, yet is a fundamental necessity for human health. Water quality could be entered under both these broad categories. In the final presentation, the Environmental Component and Environment-Related Human Health categories are integrated into one. There are other examples where the fit had to be forced, or where indicators could have fit into more than one category (Kerr, 1991).

Work is continuing to improve the conceptual framework. The emphasis is on better definition of the issue context for the indicators and the development of a more holistic framework, consistent with an ecosystem approach. This is discussed under Phase II.

Selection Criteria

The importance of criteria to guide indicator selection cannot be overstated. The criteria used for the Canadian environmental indicators project are based on two overriding factors: the need for indicators to be scientifically credible, and the need for indicators to be understandable to the non-specialist.

From various literature reviews, technical studies and consultations, a list of criteria emerged. For an indicator to be included in the national environmental indicator set, the following selection criteria should be met:

- **Scientific validity:** the indicator should be technically sound, consistent with scientific understanding of the system or element being described, and its attributed significance, defensible. There should be general consensus among credible experts that the indicators are valid.

- **Data availability/adequacy:** the data required to support the indicator should be available or it should be reasonable to assume that the data could be acquired. The indicator should be supported by sufficient data, more than one time period, to show trends over time. The security of data monitoring programs should be reasonably stable to ensure future comparable data.

- **Responsive to change:** the indicator should show changes or trends in the environment of in an environment-related human activity.

- **Representative:** the information that an indicator conveys about a phenomenon should be representative of the condition of the whole.

- **Understandable:** the indicator must be simple and clear; its significance should be fairly obvious and easily understood by those non-specialists intended to make use of them, particularly in the context of the issue to which it is related.

- **Relevance and utility:** the indicator should provide information that can be used, i.e. relevant to the needs of potential users. The indicator should be relevant to stated goals, and objectives, as well as to policies or issues of concern.

- **Target or threshold:** ideally, an indicator should have a target or threshold against which to compare it in order that users are able to assess the significance of the values associated with it.

- **Geographic scope:** the indicator should be either national in scope or applicable to regional environmental issues of national significance.

In reality, not all the indicators that comprise the preliminary national set of environmental indicators meet all these criteria.

Inevitably, the process of identifying indicators, even with the selection criteria, will involve value judgements and there are likely to be disagreements about the choice of indicators. Value judgments such as: selecting the few phenomena among a range of possibilities that best represent and relate to the objectives of the project; selecting trends that are deemed crucial to portraying accurately what is happening to the state of the environment; and assessing the significance of levels and rates of change, are part of determining scientific validity (Environment Canada, Indicators Task Force, 1991).

For the preliminary set, the single criterion that determined more than others which indicators were chosen was data availability. In some cases surrogates can make up for a lack of data for the phenomena one would like to represent, but this can result in disagreements as to their appropriateness. In most cases, it was easiest to obtain information, and thus indicators, relevant to stresses on the environment. Data availability, consistent and comparable over time and space, particularly for indicators of 'condition of the environment' or ecosystem health, is one of the challenges facing future indicator development.

Consultations

Consultations with environmental specialists, interested stakeholders and potential users have been a key element in the strategy for the National Environmental Indicators

Project from the beginning. Throughout the development of the preliminary set of environmental indicators, the Indicators Task Force worked with data experts and specialists in a variety of federal departments, principally: Agriculture; Energy, Mines and Resources; Fisheries and Oceans; Forests; Health and Welfare; Statistics; numerous agencies in Environment Canada; and the Museum of Natural Sciences. Several non-governmental organizations were also consulted during this stage. A further study with representatives from business, government-decision-makers , media and environmental NGOs, as well as members of the general public through focus groups, was conducted in the summer of 1990 to assist in communicating the indicators appropriately. This verified the needs and orientation of intended audiences and their level of interest in participating in on-going indicator development. In addition, the Public Advisory Committee to State of the Environment Reporting provides on-going advice.

Progress Report on a Preliminary National Set of Environmental Indicators

In April 1991, the federal government released a document entitled, A Report on Progress Towards a National Set of Environmental Indicators (SOE 91-1) which presented forty-three preliminary environmental indicators in 18 issue areas (see Figure 3). The report also outlined some of the major indicator development challenges in the future. These include: improving data sources to overcome recurring problems of lack of monitoring and data, incomplete or poor quality data, and inconsistency of data coverage over time and space; making better use of existing data; and where required, initiating new monitoring and surveys to generate appropriate data for indicator development. Effort also needs to be devoted to integrating environmental, socio-economic and health perspectives into the selection and presentation of indicators.

The progress report brings together for the first time, a preliminary series of environmental indicators that together provide a representative profile of the state of Canada's environment. The fundamental purpose of this initial set of environmental indicators is to serve as the basis for further discussion, elaboration and improvement of the set.

National Environmental Indicators Project: Phase II (ongoing)

Conceptual Development

The original elements of the framework: environmental goals for sustainable development, the environmental issues approach, and the stress-condition-societal response model, remain sound. However, the matrix has evolved into a "cycle" or "bubble" diagram to incorporate more of a holistic, *ecosystem* approach that shows cyclical links, instead of the rather linear aspects of a matrix. The majority of people consulted, particularly environmental organizations, felt it was critical to portray a context for the indicators and show where each indicator fits in the cycle (see example, Figure 4). It is not necessarily essential to have an indicator for each "bubble" in the cycle as long as the links can be

established. Conceptual work to understand the various links and interactions between elements in the cycle in a sustainable development context is continuing.

Indicator Development

The development and presentation of indicators is an evolving process. Indicator research and development is proceeding in the following issue areas as progress is made towards a comprehensive set of environmental indicators: climate change; stratospheric ozone depletion; acid rain; urban -air quality, -water, -green spaces, -land-use change; marine fish resources and marine environmental quality; forest resources; soil and agricultural resources; fresh water quality; biodiversity and state of wildlife; toxic contaminants in the environment; energy use; transportation; and waste management. Not only is SOER developing indicators to track changes in the natural environment but, more and more, attempts are being made to *link* these *to economic and social* (including human health) changes, both in terms of causes and effects. Ecological monitoring efforts underway now will provide, sometime in the future, indicators of the state of ecosystems rather than just their component parts. These "ecosystem" indicators can then be incorporated into the national set.

Consultations

Consultations with provincial and territorial agencies are being pursued through a variety of mechanisms, including bilateral meetings, workshops and the Canadian Council of Ministers of the Environment (CCME). A pilot study to obtain business stakeholder response to the preliminary national set of indicators was completed in February 1992, and representatives from environmental non-government organizations (ENGOs) across Canada were consulted in August 1992. Reports on the results of these consultations are available from State of the Environment Reporting, Environment Canada.

Canada is playing an active role in *international indicator activities*, particularly related to the development of indicators for OECD's country environmental performance reviews. Such activities have benefitted the national indicator development program and provided a useful venue for information exchange on innovative conceptual and methodological developments.

Environmental Indicator Bulletins

Environmental indicator bulletins are being developed as a means of regularly reporting on a national set of environmental indicators and ensuring that information is communicated in a timely and accessible manner. The concept was enthusiastically received by various stakeholders during consultations. These 2 to 6 page bulletins present graphically with explanatory text, the key environmental indicators for a particular environmental issue. The information is disseminated to the intended audiences -- decision-makers the public and media through hard copy and, eventually, electronic means. These bulletins are accompanied

by a technical supplement which gives the data tables for the indicators and provides technical notes on data sources, data reliability, etc.

Updates of environmental indicator bulletins are released as soon as the data and their analysis, for a particular environmental issue, become available. Data availability is a key factor and is dependent on the frequency with which data are collected. The Stratospheric Ozone Depletion bulletin, for example, will be released annually; indicators relying on Statistics Canada's census data collection may have a five-year reporting frequency. Some indicators may require a longer period before they display a meaningful pattern that will be useful for trend detection. Such indicators will be reported on less frequently despite the actual availability of data.

The first Environmental Indicator Bulletin on Stratospheric Ozone Depletion was released during a press conference to announce the series on November 5th, 1992 and received widespread media coverage. Since that time other indicator bulletins released or pending release are: Stratospheric Ozone Depletion, November, 1993 Update; Toxic Contaminants in the Environment: Persistent Organochlorines (March 1993); Urban Water: Municipal Water Use and Wastewater Treatment (February 1994), Urban Air Quality (February 1994); Energy Consumption (March 1994) and Climate Change (April 1994).

Database Development

SOER has established an SOER Sources Database and data files for existing indicators are now being entered and stored. The feasibility of setting up database links with Statistics Canada as a means of making indicator information more accessible is currently being explored. Research is also underway to increase the ease of updating indicator bulletins through the efficient storage of specific indicator data files.

Summary

The process of identifying and selecting environmental indicators for a comprehensive national set is an iterative one involving research, development and consultations. In Phase II it will be important to include a wider base of supporting data, from provincial, regional and municipal sources, among others. Clearly it will be necessary to rationalize differences in methods and standards between the different data sets. Many data are not available in an accessible form; it will be important to determine what can be made usable to support indicators.

If we are to report regularly on the state of the environment through indicators, we will need to improve the quality and timeliness of data, standardize information management systems, and ensure relevance to decision-making. Under the Green Plan, a network of ecological monitoring and research centres across Canada is being established which would, in the longer term, improve our understanding of ecosystem functions and relationships. Other initiatives are also underway. These range from a nation-wide survey of municipal

waste management practices carried out by Statistics Canada, to indicator research initiatives being conducted in regions of Canada such as the Arctic and Great Lakes, to the search for indicators of sustainable development by National and Provincial Round Tables on Environment and the Economy.

The enthusiastic response to environmental indicators, to date, demonstrates the clear support and keen interest by Canadians in having easily understood, credible and relevant tools to help measure progress towards the goals of sustainable development.

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Figure 1

Framework Matrix

Framework Matrix for Developing Environmental Indicators

Category	*Types of indicators* Condition (Exposure/Response)	Human activity Stresses	Management Responses
ENVIRONMENT COMPONENT/ ECOSYSTEM STATE			
ATMOSPHERE • Climate change • Stratospheric ozone depletion • Acid rain • Air quality			
WATER – FRESHWATER QUALITY • Surface water • Groundwater – MARINE QUALITY			
BIOTA (LIVING ORGANISMS) • Biological diversity • Wildlife			
LAND • Protected natural areas • Rural land conversion • Heritage sites			
ENVIRONMENT-RELATED HUMAN HEALTH			
DRINKING WATER			
RECREATIONAL WATER			
AIR QUALITY • Outdoor • Indoor			
TOXIC RESIDUES IN FOOD			
RADIATION EXPOSURE			
WASTE MANAGEMENT • Solid • Hazardous			
NATURAL ECONOMIC RESOURCES			
FORESTRY			
AGRICULTURE			
FISHERIES			
WATER USE			
ENERGY			

Figure 2

Elements of the matrix

Environmental components: atmosphere, water, biota (living organisms), and land. Gauging the health of ecosystems requires a set of chemical, physical, and biological indicators that measure environmental quality. For example: ambient concentrations of various pollutants (including SO_2 and NO_x) are chemical indicators of acid rain. Biological indicators (for example, birds or fish near the top of the food chain) can be used as measures of the state of the ecosystem.

Environment-related human health: it is necessary to have information on links between environmental quality and the potential risks to an individual's health. This includes indicators for water quality (both drinking and recreational use); urban air quality; food contamination; and waste management.

Natural economic resources: forests, agriculture, fisheries, water, and energy. Changes in the quality, quantity, and use of such resources, as measured by indicators, can tell us whether we are managing them in a manner that sustains them and the environment as a whole.

Measures of **condition** are those that refer to the quality and quantity of an environmental component or natural resource. They include the various exposures or responses (alterations/changes) of the environment to human activities.

Measures of **human activities or stress** refer to emissions and discharges, restructuring, or consumption of environmental resources that result from human activity.

Measures of **management responses** refer to the actions, policies, and programs undertaken to respond to stresses on the state of the environment or one of its components.

Figure 3

A Preliminary List of National Environmental Indicators

ATMOSPHERE

Climate Change
* Canadian energy-related emissions of carbon dioxide (CO_2)
* Atmospheric concentrations of CO_2
* Global air temperature

Stratospheric Ozone Depletion
* Canadian production and importation of ozone-depleting chemicals
* Stratospheric ozone levels

Radiation Exposure
* Levels of radioactivity in the air

Acid Rain
* Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emissions

Outdoor Urban Air Quality
- Common Air Pollutants
* Nitrogen dioxide (NO_2) and carbon monoxide (CO): Levels in urban air and emissions
* SO_2 and total suspended particulates (TSP): Levels in urban air and emissions
* Ground-level ozone concentrations
- Air Toxics
* Lead concentrations in urban air

WATER

Freshwater Quality
* Population served by treated water supply
* Municipal discharges to fresh water: BOD (biochemical oxygen demand), TSS (total suspended solids), and phosphorus
* Pulp and paper mill discharges to fresh water: TSS and BOD
* Discharges of regulated substances by petroleum refineries to water
* Concentrations of phosphorus and nitrogen in water
* Maximum observed concentrations of pesticides in water: 2,4-D, atrazine, and lindane

Toxic Contaminants in the Freshwater Ecosystem
* Contaminant levels in Herring Gull eggs in the Great Lakes Basin: PCBs (polychlorinated biphenyls) and DDE (dichlorodiphenyldichloroethylene)
* Contaminant levels in Lake Trout, a sport fish from the Great Lakes Basin: PCBs and DDT (dichlorodiphenyltrichloroethane)

Marine Environmental Quality
* Municipal discharges to coastal waters: TSS and BOD
* Pulp and paper mill discharges to coastal waters: TSS and BOD
* Volume of significant marine spills
* Area closed to shellfish harvesting
* Contaminant levels in seabird eggs: PCBs
* Contaminant levels in seabird eggs: Dioxins and furans

BIOTA (LIVING ORGANISMS)

Biological Diversity at Risk
* Wildlife species at risk

State of Wildlife
* Levels of migratory game bird populations

LAND

Protected Areas
* Land under protected status

Urbanization
* Rural to urban land conversion

Solid Waste Management
* Municipal solid waste disposal trends

NATURAL ECONOMIC RESOURCES

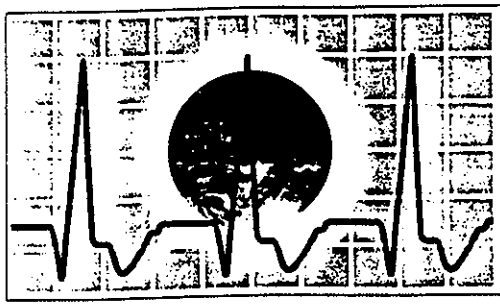
Forestry
* Regeneration success versus total forest area harvested

Agriculture
* Changes in agricultural land use
* Amount of chemical fertilizer used and its associated nutrient content
* Agricultural pesticide application on cultivated land

Fisheries
* Total commercial fish catches in Canadian waters off the Atlantic coast
* Commercial fish harvest in the Great Lakes

Water Use
* Total water withdrawal compared with growth in Gross Domestic Product (GDP)
* Rates of water withdrawal and consumption by key economic sectors
* Rates of water recirculation by key industrial sectors
* Daily household water use per capita

Energy
* Total per capita primary energy use
* Emissions of CO_2 per unit of energy consumed
* Fossil fuel intensity of primary energy demand



ENVIRONMENTAL INDICATOR BULLETIN

TOXIC CONTAMINANTS IN THE ENVIRONMENT

Persistent Organochlorines

Issue Context

Contamination of the environment by toxic substances has been associated with industrialized society since the 1800s. These substances enter ecosystems by many pathways, including industrial discharges and leakage, municipal and consumer wastes, runoff from agricultural and forestry applications, and accidents. Air and water currents can disperse these contaminants over great distances.

The dramatic growth in the number and variety of chemical products since the Second World War has led to concern for the health of both wildlife and humans. More than 35 000 chemicals are reported to be in use in Canada today. Just how many of these are toxic is unclear, but particular concern has focused on groups of contaminants that are associated with adverse effects on wildlife. One notable group is *persistent organochlorines*.

Organochlorines are a family of chemicals that have typically been used either as insecticides, such as DDT, or in various industrial applications, such as PCBs. Another part of this family, the polychlorinated dioxins and furans, are not intentionally manufactured but are by-products of certain industrial processes as well as being produced by incomplete combustion in incinerators and during forest fires.

One problem with some of these organochlorines, and the reason why they are termed *persistent*, is that it can take decades or even centuries for them to break down naturally. Because of this persistence and their high solubility in fat, they tend to accumulate in the tissues of some animals (a process called *bioaccumulation*). The contaminants are then passed through food chains and can reach very high concentrations in the tissues of predators at the top end of food webs (a process called *biomagnification*).

Concerns about the effects of persistent organochlorines on wildlife and humans arose in the early 1960s. Since then, regulations have been adopted in North America to ban the use of many of these compounds, or severely restrict their release into the environment.

The issue of toxic contaminants in the environment can be represented by the cycle of *supply*, *levels* in the ecosystem, *effects* on biota, and *societal responses*, as illustrated below. This bulletin focuses on levels of certain persistent organochlorine contaminants in biota. Measurements of contaminant concentrations in the tissues of affected species provide a warning of potential threats to ecosystem integrity, including human health. Only partial information is available on the other stages of the cycle.