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Organizing Principles for Environment Statistics

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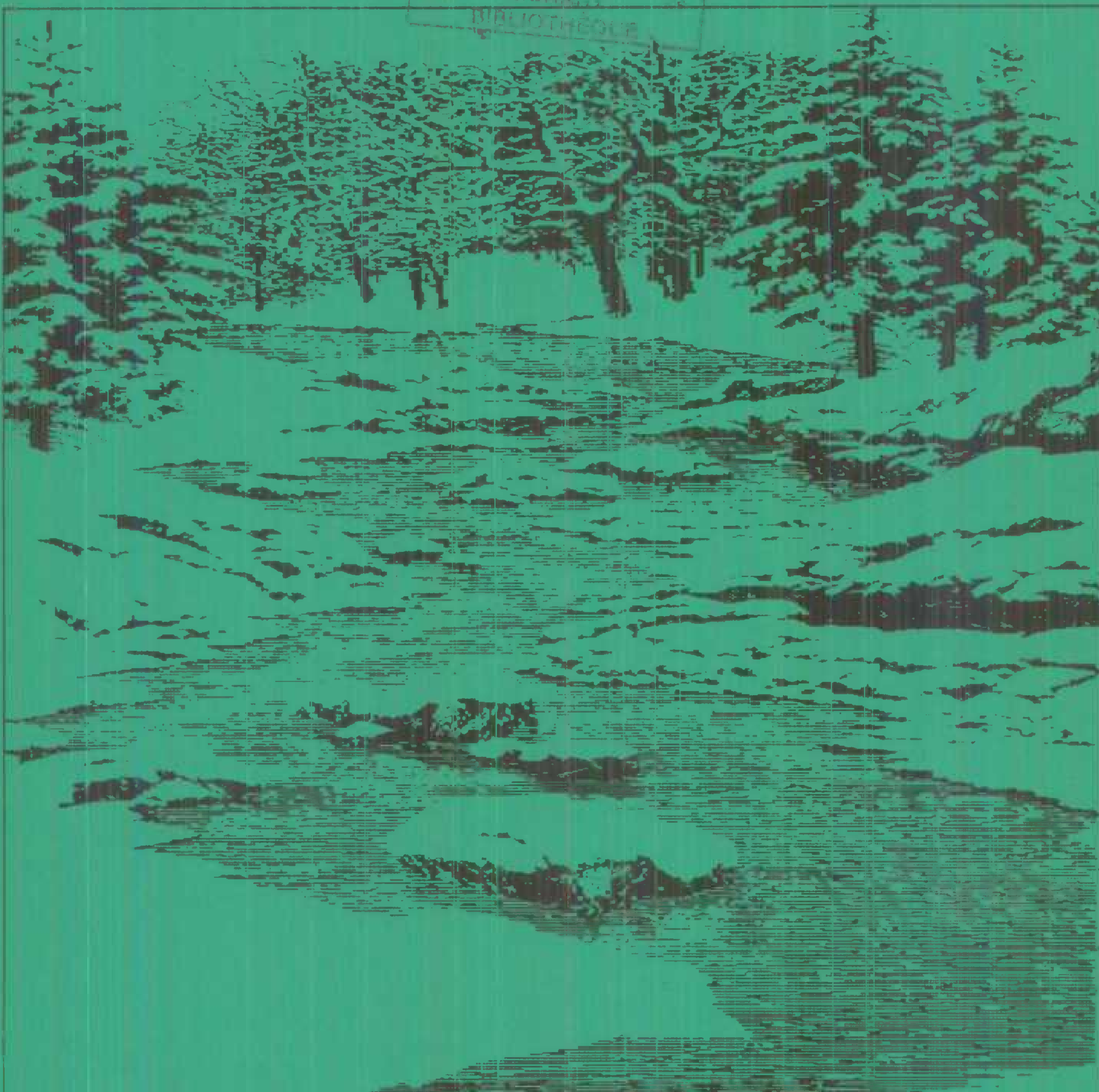

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Organizing Principles for Environment Statistics

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This paper is one in a series of internal discussion papers produced in Statistics Canada's National Accounts and Environment Division. These papers address topics related to environmental statistics and the National Accounts components which are currently under development.

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Organizing Principles for Environment Statistics

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1. Introduction

The organization of environment statistics offers challenges both old and new. Traditional problems of definitions and classifications, for example of wastes and pollutants, are common. But whole new challenges, such as the need for conceptual frameworks and the existence of gaps in our scientific knowledge, abound as well. Since "the environment" is all-encompassing and ill-understood, there is an ongoing debate among some statisticians whether we should be publishing imperfect and incomplete data or waiting for the science to catch up. This article offers some approaches, based on Canadian experience, to this still experimental subject area.

Environment statistics may be narrowly or broadly defined. At their narrowest, environment statistics would be measures of the state and quality of environmental media (land, air and water). Most national jurisdictions and international organizations, however, define environmental data to include a broad spectrum of information: human activities that impact on the environment, natural events causing environmental change, emissions of pollutants, measures of stocks of environmental assets and their state and quality, measures of living systems and organisms, and human responses to changing environmental quality (investment in pollution control, regulations, etc.). The key point in the broad definition is that, excepting certain autonomous natural events, the environmental changes of concern to citizens and governments are the result of human activities.

National statistical offices are well versed in the techniques of collecting socio-economic data. Surveys employing standard sampling techniques to well-identified universes are their stock in trade. It is worth noting, therefore, some important differences between traditional socio-economic data and physical data about the environment:

- *Measurement Error.* Most socio-economic data are survey-based; measurement error relates to questionnaire design and the understanding of human cognitive processes; quantifying the difference between what you wish to measure and what you really measure with a survey may be problematic. Most environmental data are measured using scientific instruments for which calibration standards can ensure repeatability, in principle if not in practice.

- *Sampling Error.* For socio-economic survey data there are well-developed theories of sampling from populations that permit the estimation of error bounds. For a considerable body of environmental data the underlying distributions are not known; sample error may relate to time, the sampling frequency compared with the potential rates of change of the phenomena being measured; or it may relate to space, the number and distribution of sample points required to draw conclusions about larger geographic units.

- *Summarization.* Many socio-economic data are extensive (number of individuals, value of shipments, etc.) and so may be summed to provide aggregates. A considerable proportion of environmental data are intensive (concentrations of pollutants in water, air or soil, for instance) and therefore may not be summarized or averaged without auxiliary information.

This article will present some of the statistical infrastructure needed for environment statistics, examine the human activity dimension of these statistics and describe an experimental conceptual framework for their organization.

2. Statistical Infrastructure

The initial activity for the statistician in any subject area is to define the extent and nature of the problem and to define a model, however informal, of the system to be measured. This has many aspects in the environmental domain.

Scope. "The environment" can be many things: the natural environment, the built environment, or the indoor environment. Most statistical activity has concentrated on the natural environment and some aspects of the built environment. Examples of the latter include measures of green space, water and sewage treatment and waste management - the statistician must beware, however, that statistics of the built environment do not expand into the broader area of social indicators. The natural environment is generally construed as the non-urban area, including near-shore waters.

Scale and Geography. While environmental change and its causes may be global or continental in scale, a significant proportion of environmental problems are localized in space and time. In most instances, therefore, each datum in an environmental data base should have a georeference (such as longitude and latitude). For reporting of environmental data, natural geographic boundaries, as opposed to administrative ones, are required - examples include ecological zones, watersheds, soil and climatological regions, wetland boundaries, and forest zones. As pointed out in Hamilton and Trant (1989), however, introducing geographic location as an attribute of data opens up whole new vistas of potential statistical error, including the accuracy of georeferencing and of summarization of data to environmental boundaries.

Classifications. The broad definition of environment statistics leads to requirements for several types of classifications: (i) environmental components (land, air and water); (ii) human activities and institutions affecting the environment; (iii) materials emitted into the environment; and (iv) the types of physical and biological restructuring of the environment.

Conceptual frameworks also form part of the statistician's toolkit. Before discussing frameworks, though, we examine in detail the human activity dimension of environment statistics.

3. Classifications of Human Activities by Environmental Impact

Because of the desirability of measuring pressures on the environment as well as the nature and consequences of environmental change, much of the existing socio-economic data collected by statistical agencies are valuable for environment statistics. Examples of directly relevant data include:

- capital and operating expenditures on pollution abatement and control;
- measures of the provision of environmental goods and services; these include municipal government spending on waste management and water and sewage treatment, environmental services, and the production of specific environmental protection goods (e.g. scrubbers) by manufacturers;
- morbidity and mortality data relating to disease with a likely environmental cause.

Other socio-economic data may serve as proxies for environmental impact or, for population data, as measures of the population "at risk" from environmental deterioration. Generally these data must be georeferenced to highlight their environmental relevance; they are particularly valuable when combined with physical data, such as emissions and loadings. Examples of these data include:

- resource sectors (activity levels, selected inputs and outputs);
- industry sectors (activity levels, selected inputs and outputs);
- agriculture;
- population census;
- energy consumption;
- transport statistics.

In what follows we will develop two examples of how classification of this socio-economic data by potential environmental impact increases its value for environmental analysis.

The first example is agricultural data. Agricultural practices can have profound environmental consequences, both with respect to conservation of the soil resource and to off-site effects. Tillage practice affects rates of soil erosion, as does the prevalence of wide-row (with substantial soil exposure to wind and water) or narrow-row crops. Monocultures (large areas under a single crop) increase risk of damage from insects and disease and generally require higher inputs to control these pests. High levels of fertilizer inputs increase the risk of nutrient runoff into waterways. Trant and Trepanier (1990) have used these and other criteria to classify all Canadian farms by potential environmental impact using census of agriculture data. They classify farms into one of five types:

- *Specialty farms.* These are typically small specialized operations such as plant nurseries, market gardens or greenhouses. Their environmental impact is generally small.
- *Non-cropping farms.* Generally livestock operations, the environmental impact of these farms is small except where there are large concentrations of animals near waterways. Most of the land is unimproved pasture with low inputs and low risk of erosion.
- *Wide-row monoculture farms.* Farms growing predominantly one wide-row crop have the largest potential impact on the environment. With wide-row crops soils are exposed to erosion, and high inputs of fertilizer are required. As noted previously, monocultures need high levels of pesticide application to keep weeds, insects and disease at bay.
- *Close-row monoculture farms.* Associated with dry-land agriculture, these farms share the problems of other monocultures. To conserve soil moisture summerfallowing is a common technique, with consequent risks of wind erosion.
- *Rotational farms.* Farms that grow a wide variety of crops will typically exhibit lower inputs of fertilizer and pesticides. In addition, rotating crops can improve soil structure.

Because each farm is georeferenced in the Canadian census of agriculture data base, this classification can be used to map areas where the potential for environmental deterioration from agricultural practices is high.

A second example of classification by environmental impact concerns industry data. In three editions of *Human Activity and the Environment* (Statistics Canada 1978, 1986, 1991) industries have been grouped according to their environmental impact. In the first two editions a one-way classification of sectors into high, medium or low impact was employed. The 1991 edition developed a multi-way classification described below. The essential purpose of these classifications is to permit mapping of the locations of potentially hazardous industrial activities (as opposed to simply mapping concentrations of industrial activity).

Industries interact with the environment in several basic ways: (i) they may harvest or extract resources directly; (ii) they may require large resource inputs, including water; (iii) they may emit pollutants to air or water; or (iv) they may use materials that are potential contaminants that may be emitted to the environment. For the purposes of the classification presented below, examples of potential contaminants include radioactive substances, asbestos, heavy metals, coal tar, CFC's, equipment containing PCB's, hazardous chemicals such as benzene or carbon tetrachloride, carcinogens such as vinylchloride monomer, and toxics such as sodium cyanide. Large industrial energy consumers are assumed to be the potential air polluters.

The general principle in classifying industries by environmental impact is to rank sectors according to their *intensiveness* in a given characteristic, for example value of energy consumed per dollar of output. The data for performing the classification come largely from the Input-Output accounts. The basic classification of potential environmental impact is as follows:

- harvesters and extractors of natural resources, including agriculture;
- resource intensive sectors, the primary transformers of raw materials;
- energy intensive sectors;
- contaminant intensive sectors;
- water intensive sectors.

Input-Output (I/O) data and data from a survey of manufacturing and primary industry water use were used to classify all 150 I/O sectors into high, medium or low ranking for each of these categories. Rankings for selected industry sectors are presented in Table 1.

TABLE 1. Environmental Impact Ranking of Selected Sectors

	Impact Category				
Sector	Havesting & Extraction	Raw Resource	Energy Use	Potential Contaminant	Water Use
Iron mines	High	Low	High	Low	Low
Dairy products	-	High	Low	Low	Med.
Clothing	-	Med.	Low	Med.	..
Pulp and Paper	-	High	High	Med.	High
Non-ferrous smelting	-	High	High	High	Med.
Motor vehicles	-	Low	Low	High	Med.
Non-metallic mineral prod.	-	High	High	High	High
Industrial chemicals	-	High	High	High	Med.
Truck transport	-	Low	High	High	..
Laundries and cleaners	-	Med.	High	High	..

Note: - means not applicable, .. means no data

The result of this ranking is a non-disjoint classification of industry sectors according to potential environmental impact. For instance, the non-metallic mineral products industry ranks as a high environmental impact sector along all four intensiveness axes: resource consumption, energy consumption, use of potential contaminants and water consumption. The multi-dimensional classification permits considerably more precision in classifying sectors according to their potential impact than a simple categorization would give.

Suitable re-classifications of existing socio-economic data can increase their pertinence to environmental issues. Having explored this and some of the infrastructure items in environment statistics, the next question is how to make all of this fit together. This is the subject of the next section.

4. An Experimental Framework for Environment Statistics

If statistical development is not to be haphazard, a conceptual framework is required to delineate the major components and inter-relationships that are important in understanding and describing environmental issues. From the conceptual framework taxonomies and classifications can be defined.

While there is a scientific aspect to the development of frameworks, in the sense that a good framework should be an accurate representation of the system to be measured, there is also the consideration of policy relevance: the properties to be measured must be germane to the policy issues of the day. The policy concerns about the environment are wide-ranging:

i. How do we establish standards for environmental quality? These standards must balance human health, economic sustainability, integrity of global systems, and aesthetic values.

ii. How do we achieve these standards most efficiently?

The ideal framework for environmental statistics would therefore encompass these issues and be integrative in the manner of the System of National Accounts (SNA) in the economic domain. The analogy with the SNA breaks down, however, in the face of our still-imperfect understanding of the relationship between complex inputs to and impacts on the environment and the responses of environmental systems. A workable framework for environment statistics must be able to deal with gaps in understanding.

There is no lack of alternative frameworks for environment statistics. Every author or institution that has published a State of Environment (SOE) report or compendium of environment statistics has applied a conceptual framework to the organization of their work. Sheehy (1989) has provided a useful classification of current approaches to environmental reporting and, by implication, to the frameworks that have been developed. These may be summarized as follows:

- *Issues.* Many publications are built upon a set of current policy issues as the means of organization. Therefore issues such as acid precipitation, global warming, and soil loss can provide a skeleton for the report and other environmental data can be arrayed around these issues. This approach has the advantages of timeliness and topicality. What it lacks, however, is comprehensiveness and a systematic approach and, in common with the next two frameworks discussed, it may overlook or ignore important, cross-cutting problems.
- *Resource sector.* While reports in this category generally go beyond simple enumeration of trends in natural resource extraction and the environmental consequences that follow, a substantial portion of the framework is provided by the classification of resource activities - agriculture, forestry, fisheries, mineral extraction and energy production. Such a framework provides information that is readily related to the benefits we take from the environment as well as many of the economic implications of environmental change (for instance decline in productive forests and fish stocks).
- *Environmental media.* The most traditional organizational framework for environmental data divides the world into the usual categories of land, air and water. This has the advantage of familiarity - we can all relate to air that is unbreathable or water that is polluted - but is weak in categorizing cross-media and biological effects.

- *Environmental process*. This approach is based on measurement of the physical and biological processes fundamental to natural ecosystems and the human activities that have impacts upon them. Concentrating on environmental processes is both systematic and integrative, in the sense that all human and natural agents of change will eventually produce alterations in ecosystem operation.

Not surprisingly, Sheehy's final category of environmental framework is the combination approach, wherein aspects of several organizing principles are applied. This can be seen clearly in the *State of Environment Report for Canada* (Environment Canada (1986)) which combined resource sector and environmental process approaches.

There are at least two published frameworks for environment statistics that are independent of specific environmental reports: the United Nations' Framework for the Development of Environment Statistics, and Statistics Canada's STRESS system.

The *Framework for the Development of Environment Statistics (FDES)* (United Nations 1984) was intended as a guideline for statistical agencies embarking on work in the environmental domain. It adopts a tabular organization, in which rows are environmental components and columns are categories of information.

The components distinguished in the framework include flora, fauna, the atmosphere, water, land, and human settlements; information categories include socio-economic activities, natural events, environmental impacts of these activities and events, responses to these environmental impacts, and stocks, inventories and background conditions.

The information categories adopted lack the precision to distinguish clearly human activities, the byproducts of those activities that cause environmental problems (the stressors) and the problems created (the measures of stress). The category "responses to environmental impacts" is limited to human actions resulting from perceived environmental change.

This is a traditional environmental media (or components) framework that attempts to apply a novel classification of categories of information about the components. It therefore suffers from some of the weaknesses of media approaches, especially in dealing with cross-medium impacts.

The *STress Response Environmental Statistical System (STRESS)* (Friend and Rapport, 1979) has been an influential alternative to media and resource sector approaches. It postulates a categorization of data according to a model of activities producing stresses on the environment, environmental systems responding to these stresses, and finally humans taking remedial actions. It again adopted a tabular organization, in which activities (both human and natural) are the row categories and the columns are the stressor measures, measures of environmental stress, environmental response to these stresses, human response to environmental change, and measures of stocks. Activities are categorized into generation of waste residuals, permanent environmental restructuring, harvesting, extraction of non-renewable resources, production and consumption of potentially hazardous substances, energy production and consumption, natural activity, and population dynamics.

The STRESS framework employs a natural conceptual model for biologists, who are used to thinking about stresses and responses in natural systems. This does not make it a practical framework for statistics, however. The Achilles heel of the STRESS framework, which led to its modification in practical applications (see, for instance, Statistics Canada (1986)), is the assumption that individual stresses could be associated with individual responses - in reality changes in environmental state are a complex reaction to a wide array of inputs resulting from human and natural activities.

The fault this system shares with the UN FDES is structural - imposing a tabular organization on the phenomena to be measured means that cross-medium impacts will be difficult to handle in the FDES, while cross-activity impacts will be difficult for STRESS. While advances in environmental science will increase our understanding of the relationships between individual stresses and responses in the environment, it is likely that complexity will always rule: any given change in environmental state will be the result of a complex of stresses on the system.

With these limitations in mind, therefore, what follows is the description of an experimental framework employed in the latest edition of *Human Activity and the Environment* (Statistics Canada 1991). The Population-Environment Process (PEP) framework attempts to develop a conceptual model and associated framework for data that integrates information on interactions between human populations, their artifacts and the natural environment. But before exploring the concepts in PEP a definition is required.

All impacts on the natural environment resulting from human activities can be viewed as *restructuring* of the environment. This can have three basic expressions: (i) *physical* restructuring results from construction of dams, roads, power lines, mines, dump sites and other changes to the natural landscape; (ii) *chemical* restructuring results from the release of pollutants and wastes into the environment; (iii) *biological* restructuring is the result of harvesting and the introduction of exotic species. Viewed this broadly, restructuring is a convenient term to summarize the range of impacts humans have on the environment.

Figure 1 presents the conceptual diagram for the PEP framework. The principal ideas are as follows:

- The socio-economic system is an artificial system (in Herbert Simon's phrase (1982)) embedded in the natural environment.
- The human created and controlled processes within the socio-economic system have two types of direct impact on the environment: restructuring as a byproduct of production and consumption, and extraction, harvest and use of the natural environment as processes providing the necessary inputs to the socio-economic system.
- The natural environment has cycles and processes that are affected by the outputs of, and inputs to, the socio-economic system, and the state of the environment changes as a result.
- The change in the state and quality of the environment affects in turn the types and quantities of materials and organisms that are available to the socio-economic system.

The critical idea in this is *closing the loop*, that the by-products of socio-economic activity interact in the environment to produce changes in the resources (including air, water and wilderness) on which these activities depend. In translating this idea into a scheme for statistical measurement, the conclusion is that activity levels, restructuring, environmental state, and the quality and quantity of resources available for extraction and harvest are all important to measure.

The implications of the conceptual model for statistical measurement are made concrete in Figure 2, the structural diagram. What follows is a narrative description of the components of the PEP framework as seen in this figure.

- The population appears as a stock dependent on a set of population processes (birth, death, and migration). This population consumes services and non-durable goods produced by a set of socio-economic processes, which are in turn based on a capital stock of durable human-made items.
- The population also interacts directly with stocks of natural assets in the environment, through breathing air, drinking untreated water, activities such as fishing, hunting, gathering, collection of firewood, and the enjoyment of the aesthetics and amenities provided by the natural world. Direct use of the environment by the population inevitably leads to some restructuring, both physically and

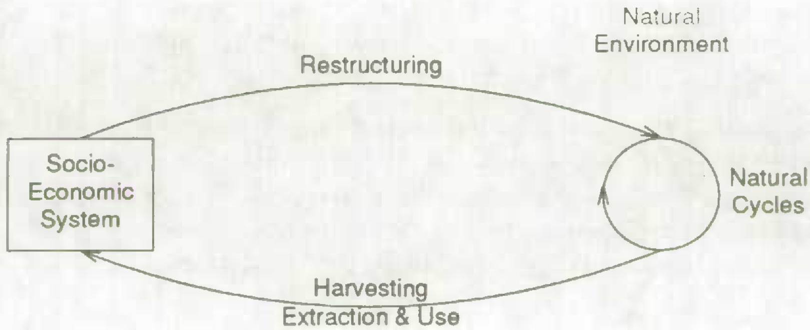

Figure 1. Population-Environment Process Framework Conceptual Diagram

through the release of wastes.

- Socio-economic processes require flows of resources (both living and non-living) and services from the stocks of natural assets. As by-products of production and consumption the full range of restructuring of the natural environment occurs. Socio-economic processes depend on the capital stock of human-made assets.
- Unwanted by-products of socio-economic processes are stockpiled, for instance in dumps and landfills. These waste stocks may be recycled and returned to the processing stream, or some of them may leak into the natural environment.
- The stocks of natural assets change as a result of interactions with the population, socio-economic processes, leakage of wastes and natural processes (including growth and decline of living populations, other biological processes, and geochemical processes).

As with any model, the PEP framework forces some categorization of data in ways that may not seem natural. Examples of this include: (i) the linkages between population and natural assets are direct and unmediated by socio-economic processes - therefore waste disposal must appear as a socio-economic process; (ii) only goods that are physically consumed flow from socio-economic processes to the population - therefore driving a car or heating a home must appear as a socio-economic process; (iii) agriculture is split between natural assets and socio-economic processes - agricultural land is a natural asset, but the operation of a farm is a socio-economic process with its associated capital stock.

A strength of the PEP framework is the linkage it provides between disparate data - a degree of integration is therefore achieved:

- The framework encompasses measures of socio-economic processes that are the subject matter of existing surveys, for example agriculture, primary industries, manufacturing, services including transportation, and capital formation. Capital stock is also measured by socio-economic surveys - of particular interest is that portion of investment that is for pollution abatement and control.
- Population state and population processes are standard health and demographic data.
- The natural asset component of the framework incorporates existing natural resource data.
- Linkages to the System of National Accounts are explicit: consumption and investment (two of the flows associated with the socio-economic process component of the framework) make up a

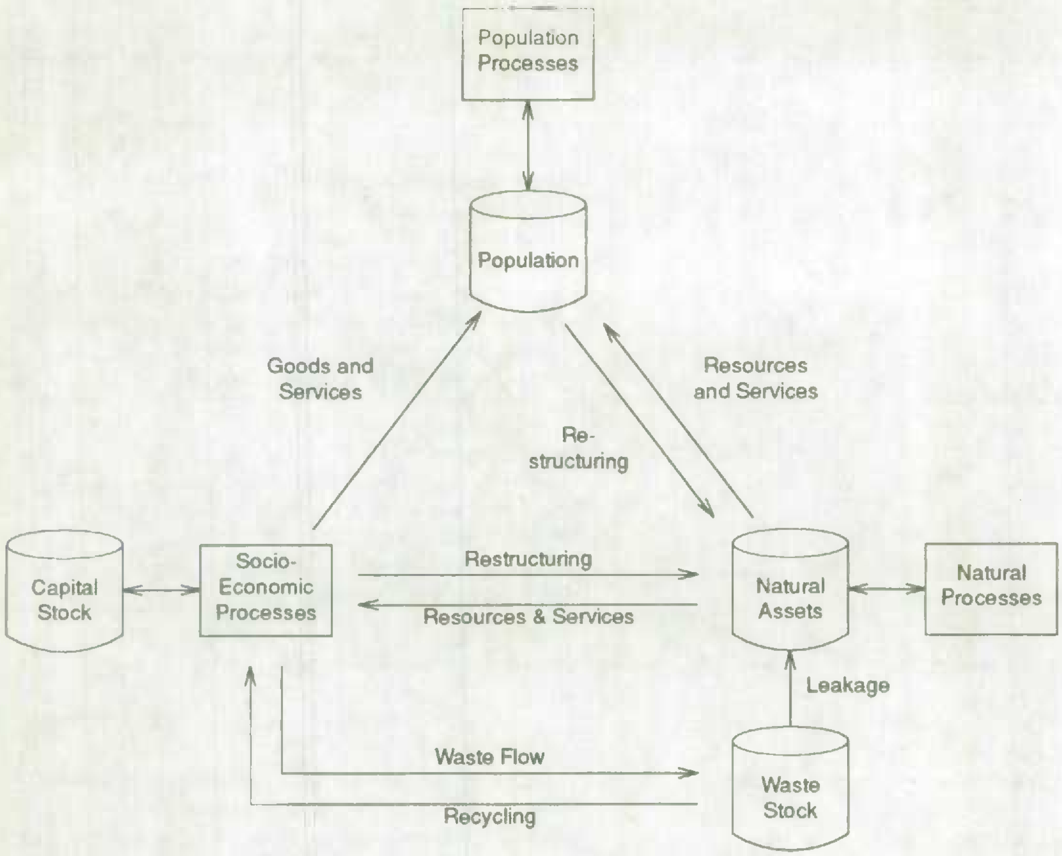

Figure 2. Population-Environment Process Framework Structural Diagram

substantial portion of Gross Domestic Product; the capital stock constitutes a part of tangible assets in the National Balance Sheet. The framework suggests the desirability of measuring natural assets as another type of tangible asset within the National Balance Sheet Accounts (Statistics Canada (1987)).

While the PEP framework is comprehensive, the intention is not to re-label the mass of existing socio-economic data as "environmental" simply because they fit into the framework. The attempt is to show how traditional environmental data (emissions, loadings in media and biota, measures of physical and biotic state) can integrate with socio-economic data to provide a more complete picture of how environmental quality may be related to socio-economic activities and how socio-economic activities may be influenced by changing environmental quality.

The structural diagram in Figure 2 provides a useful taxonomy of the components of the framework, from which may be derived a classification of the variables that the statistical system should measure. Three major components can be seen: stocks (represented by "barrels" in Figure 2), processes (represented by boxes) and interactions (represented by arrows). The types of variables relating to these components fall into four categories: states, activities, flows and restructuring. A first attempt at classifying these variables and components is shown in Table 2.

TABLE 2. The PEP Framework: Components and Variables

Component	Variable Type	Examples
Stocks		
Population	State	Number of people. Number of households. Health status.
Capital	State	Stocks of capital for pollution abatement and control, by sector, by material controlled. Built-up area. Transportation infrastructure including energy transport.
Natural Assets	State	Quantity and quality of minerals and energy. Quantity and quality of living resources. Air quality. Water quantity and quality. Amount and quality of wilderness.
Wastes	State	Quantity of wastes. Number of landfill sites.
Processes		
Population	Activity	Growth, migration.
Socio-economic	Activity	Outputs by sector. Production and consumption of environmentally dangerous substances. Energy consumption. Operation of transportation stock.
Natural	Activity	Rates of geochemical cycles. Natural events (storms, earthquakes, fires, pest infestations).
Interactions		
Socio-economic process with Population.	Flow	Contaminants in food and other goods.
Natural assets with Population.	Flow	Air quality in populated areas. Sport fishing and hunting. Ground water withdrawals.
Natural assets with Socio-economic processes.	Flow	Extraction of minerals and energy. Water use. Harvest of forests, fish and wildlife. Agricultural production.
Population with Natural assets.	Restructuring	Impacts of visits to wilderness and protected areas. Impacts of extracting local environmental resources (e.g. firewood).
Socio-economic processes with Natural assets.	Restructuring	Physical restructuring through development of agriculture, mines, dams, and transport infrastructure. Biological restructuring through harvesting activities.
Wastes with Natural Environment	Flow	Release of pollutant emissions and wastes, breakdown of wastes.
Socio-economic processes with Wastes	Flow	Generation of waste materials, recycling.

As noted at the beginning of this section, the policy issues with respect to the environment are wide-ranging. The PEP framework is an explicit attempt to organize data that encompass this range, from measures of human population to measures of the socio-economic system created by humans and finally to measures of the natural environment on which this system, and human well-being, depends. It is difficult to be precise about the criteria for adopting or rejecting a statistical framework. The criteria tend to be pragmatic: are there phenomena in the environment that are difficult to represent and classify within the framework? Experience to date with the PEP framework, employed in the 1991 edition of *Human Activity and the Environment* (Statistics Canada 1991), has been positive.

5. Concluding Thoughts

Several themes in the development of environment statistics have run through this article: the need for georeferenced data and appropriate spatial frameworks; how re-classification of socio-economic data can accentuate its usefulness for environment statistics; and the need for frameworks within which to develop and present environment statistics. These concluding thoughts concern frameworks.

A principal use of a framework for statistical data is to identify data gaps. A comparison of the types of data corresponding to the components and variables of the PEP framework, for instance, with available data would give a clear indication of where gaps lay in a statistical system. What a framework cannot do, since its role is structural, is rank priorities for data collection. To do this requires either a model, identifying the critical points in the interaction between natural and human-made systems, or a *numeraire* such as a dollar value to measure the relative importance of the various environmental problems and therefore priorities for data collection. In both cases the prime limitation is likely to be our imperfect scientific understanding of the environment.

As well as data gaps, therefore, as statisticians we are faced with knowledge gaps, principally about the cause and effect relationships in the environment. As John Bailar (1988) has pointed out, the problem in understanding environmental change and its effects on humans is not simply one of random variability - it is a problem of uncertainty, where key relationships in our models are unquantifiable. This may be either a consequence of our incomplete scientific knowledge or of the inherent complexity of natural systems.

What challenges do knowledge gaps present to framework development? As noted earlier, frameworks such as STRESS assume a quantifiable relationship between individual pressures on the environment and individual environmental responses, in effect denying the knowledge gap. The PEP framework, on the other hand, suggests it is important to measure both pressures on the environment and the state of the environment, but no strong claim is made regarding the precise relationship between these phenomena. However, as scientific understanding grows it should be increasingly possible to quantify the role that natural processes play in the transformation of pressures on the environment into changes in environmental state - the framework therefore contains the necessary components to capture new knowledge and new data.

A good framework should also suggest new avenues for research and data development. The conformance of the PEP framework with the SNA suggests useful paths to explore in wealth accounting, as mentioned previously (see, for instance, Hamilton (1991)). Showing the human population explicitly in PEP, and its direct and indirect links with the environment, offers ideas on the usefulness of household surveys, both for developing countries where direct reliance on the natural environment is high, and for developed countries where interaction with the environment is mediated by such things as recycling programmes, purchases of recycled products, and equipment to conserve water and energy.

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SUMMARY

Broadly defined, environment statistics go beyond measures of the state and quality of environmental media to include the human activities affecting environmental quality. Organizing statistical efforts in this domain requires not just classifications of pollutants, but novel classifications of existing elements of the national statistical system as well, for example classification of farms and industries by potential environmental impact. New geographic frameworks such as river basins and ecological zones must augment traditional administrative and census boundaries. At a deeper level, workable conceptual frameworks are required to organize and guide statistical development - in this regard the experimental Canadian Population-Environment Process Framework is described. The challenges presented by data gaps and knowledge gaps are discussed.

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3. Smith, Robert (September 1990): ***An Annotated Bibliography of the Resource and Environmental Accounting and Valuation Literature.***
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