

Emerging Environmental Issues



Walter Orr Roberts Lecture

Ted Munn,* Peter Timmerman,* and Anne Whyte[†]

ABSTRACT

Emerging environmental issues are issues that may someday be of concern but that have not yet been generally recognized. A review of such issues that have occurred over the last 50 years reveals that many of them have erupted rather suddenly (e.g., stratospheric ozone depletion, acid rain). However, some issues were recognized long ago by the scientific community (e.g., land degradation, overconsumption of freshwater), but for economic or other reasons governments have refused to act.

The authors of this study were commissioned by the United Nations Environment Program and the Scientific Committee on Problems of the Environment to carry out a global survey of emerging environmental issues, using the responses received to questionnaires that were sent to scientists, managers, and policy makers around the world. It had been hoped that a short list of priority issues could be identified but the number of issues was very long. However, the issues could be divided into four major classes:

- 1) Transformations of old issues; continually evolving, and in most cases broadening, in response to increasing scientific and technological knowledge and to changing socioeconomic, cultural, and environmental conditions.
- 2) Policy issues, the long-term environmental consequences of which may already be of concern.
- 3) Accidents waiting to happen, for example, chemical time bombs.
- 4) Surprises in the nonlinear responses of ecosystems to new and different stresses, as well as in the nature of socioeconomic drivers of environmental change.

In a subsequent study, the authors applied the lessons learned in the global study to an examination of emerging environmental issues in the province of Ontario, Canada.

1. Introduction

The study of emerging environmental issues has become a growth industry in the last few years. Perhaps this is due to millennium angst. Whatever the reason, the motivation for such studies is the hope that early identification of emerging issues will assist in 1) developing research priorities over the midterm (the next 5 years), 2) designing appropriate early warning monitoring systems, and 3) providing insight into policy re-

sponses that might be taken before an issue has actually become a serious threat to society and/or the biosphere.

Some of these studies are international in scope, while others are concerned with setting priorities for national or local jurisdictions. There are two main entry points into the identification of future environmental issues. One is to ask experts or other groups to predict future environmental trends and events. The other is to focus on technology forecasting and then to identify the future environmental consequences of new technological developments. Since technology forecasting involves the interests of both government and the private sector, there are more resources available to undertake the surveys and analysis. Some of the longest running forecasting programs are therefore technology oriented, such as the Japanese National Institute of Science and Technology Surveys, which have been undertaken every five years since 1971.

*Institute for Environmental Studies, University of Toronto, Toronto, Ontario, Canada.

[†]Mestor Associates Ltd., Russell, Ontario, Canada.

Corresponding author address: Ted Munn, Institute for Environmental Studies, University of Toronto, Toronto, ON M5S 3E8, Canada.

©2000 American Meteorological Society

Examples of some recently published assessments of emerging environmental issues include the following:

- A global perspective produced by the Scientific Committee on Problems of the Environment (SCOPE) for the United Nations Environment Programme (UNEP) (Munn et al. 1999).
- A study of emerging environmental issues in the province of Ontario, Canada (Munn 1999).
- A global survey of future world issues including environment, organized by the Millennium Project of the United Nations University (Glenn and Gordon 1997).
- A series of national level technology forecasts for Japan every 5 years since 1971 with analyses of environmental technology and environmental consequences. The last survey was produced in 1997 (NISTEP 1997).
- A national survey of technology and environment futures organized by the U. K. Technology Foresight Programme with an interactive World Wide Web site (<http://www.first.foresight.gov.uk>).
- A workshop report prepared by the State of California and available on the World Wide Web (<http://oehha.ca.gov/scientific/emergel.htm>).
- A Canadian provincial survey of experts and public perceptions of future environmental issues for Alberta (ECA 1995).
- A local study of future environmental risks facing the Houston area, used both for municipal priority setting and for public education (HARC 1996).

The following discussion concentrates on some results obtained from the first two studies in which the authors were personally involved.

2. Definition of an emerging environmental issue

An emerging environmental issue is defined in this paper as

- an issue (positive or negative) that may someday be of concern but that has not yet been generally recognized;
- an issue that may be global, regional, or local (if it occurs in many parts of the world);
- the issue may be caused by political, social, economic, technological, financial, institutional, or

cultural changes, or may be due to natural causes (e.g., drought, floods);

- the issue may be based on evidence or theory that suggests potentially large environmental change, which is either not widely accepted or has a low probability of occurrence; or
- the issue may be widely recognized by scientists but as yet no adequate policy responses have been taken. (For example, Professor V. Kovda, an internationally recognized soil scientist from Moscow, warned Soviet authorities several decades ago of the long-term impacts that would follow the continued uncontrolled water abstraction from the rivers flowing into the Aral Sea. Nobody listened to him!)

There is some difficulty over the use of the word “emerging.” The scientific issue of climate change, for example, has been discussed for decades, so it is certainly not new. And it reached the policy agendas of many governmental and intergovernmental bodies in the 1980s, so it is no longer an emerging issue. Yet new aspects of the issue are constantly evolving, and these can properly be called emerging issues. For instance, Table 1 shows some frequencies of low lake levels in Lakes Superior, Michigan, and Erie over the historical period 1900–79 (before the impact of climate warming could be expected to be observed) compared with simulated frequencies for a doubled greenhouse gas atmosphere, and for the doubled greenhouse gas atmosphere plus an assumed increase in water consumption in the Great Lakes basin. The frequency of low lake levels increases dramatically, and the realization of this, together with the fact that this will be superimposed on the natural variability of the system, is just beginning to be recognized as a serious long-term water management problem in the Great Lakes basin.

3. Lessons from the past; how have emerging environmental issues been identified and how have they evolved?

It is instructive to see how emerging issues developed over recent decades. Perhaps we can learn from historical analogies. A list of global environmental issues that emerged over the past 50 years has been published (Munn et al. 1999), supplemented by a list prepared specifically for Ontario (Munn 1999). Some

examples taken from these lists include the London 1952 smog, the Antarctic stratospheric ozone hole, acid rain, climate change, Chernobyl, introduction of the sea lamprey into the Great Lakes, and mercury contamination of the biosphere. Retrospective assessments suggest that some of these issues could have been identified earlier than they were, but in other cases the issue came as a complete surprise.

As examples of the latter type, we offer the following:

- 1) Power stations began to install precipitators in the late 1940s to remove particulate matter from chimney emissions. But some of the particulates contained base materials of high pH, which neutralized some of the sulfur compounds, the net result of using precipitators being that emissions became more acidic. A 1950 assessment of the impacts of a proposed coal-fired power station would probably not have detected the emerging acid rain issue of the 1960s.
- 2) Similarly, a 1950 assessment of the environmental impacts of chlorofluorocarbons (CFCs) would not have raised an alarm about the possibility of stratospheric ozone depletion. At that time, CFCs were believed to be chemically inert. [In the 1960s, ozone destruction became a concern in the context of supersonic transport (SST), but that issue went away when it was decided not to construct fleets of SSTs.] Not until after publication of the critical paper of the Nobel Laureates Molina and Rowland (1974) did the issue begin to simmer, and it was not until publication of a paper published a decade later by Farman et al. (1985) revealing increasing stratospheric ozone depletion over Antarctica that the issue became a major international concern. [P. Crutzen (see SchellInhuber 1999) has noted recently that it is only a lucky accident that fluorides rather than bromides were used in the manufacture of CFCs; bromides are 100 times more potent than fluorides in destroying stratospheric ozone.]
- 3) Another interesting example is the acid rain issue, which was first raised by the Swedish agricultural scientist, S. Odén, in the 1960s. Svante noted that many Swedish rivers and lakes were becoming more acidic, and he speculated that this was caused by

acidic precipitation, some of which was brought to Sweden from eastern Europe, the Ruhr Valley, France, and the British Isles. At the time this was a new and radical idea but Svante had a strong television personality, and he was able to persuade the Swedish people and their government that Sweden had a serious problem that the Swedes could not solve on their own. Svante's persuasive manner was a factor in the Swedish decision to ask the United Nations to hold an intergovernmental conference in 1972 on the human environment. Although evidence of sterile lakes had been found in the Georgian Bay area of Ontario a decade earlier, "acid rain" did not become an issue in North America until several years after the Stockholm Conference.

These case studies illustrate the uncertain progress of new issues as they move toward the priority agendas of scientists and government agencies. Equally uncertain are the long-term projections of environmental "futures." Here are a couple of examples.

- 1) A national conference was held in Ottawa in the 1960s for the purpose of trying to identify the major problems facing Canada in the year 2000. After considerable debate within the environmental subpanel, it was decided that the main environmental issue would relate to the increasing number of workers on 4-day weeks in the industrial cities of Seattle, Detroit, Cleveland, and Buffalo in the United States and Hamilton, Toronto, and Oshawa in Canada. This would lead to a surge in weekend recreational tourists in neighboring parts of Canada, greatly inflating lakeshore property val-

TABLE 1. Frequency of low water levels in the Great Lakes. This table shows the percentage of time when historical water levels were, and future water levels would be, equal to or less than the severe low levels of 1963–65 (R. Street 1999, personal communication).

| Lake | Historical (1900–79) | Doubled CO ₂ | Doubled CO ₂ + increased water consumption |
|----------|----------------------|-------------------------|---|
| Superior | 10 | 61 | 79 |
| Michigan | 8 | 57 | 77 |
| Erie | 5 | 38 | 77 |

ues and overwhelming highway systems. An early warning indicator of this emerging issue would include an annual tally of trends in the number of people working 4-day weeks. Of course, the issue never really surfaced.

- 2) Another scenario that was nearer the mark (but nobody believed it at the time) is contained in the report of a workshop on surprising futures held in Sweden in 1986 (Svedin and Aniansson 1987, p. 54). The objective of the workshop was to look at a range of socioeconomic scenarios for various parts of the world up to the year 2075. One of these posited the collapse of the Soviet Union in year 2017, brought on by the increasing pressure from Muslim republics to the south and east. The scenario proved to be right, but for a different reason, and it occurred much earlier than expected.

These examples illustrate the difficulties faced by anybody trying to predict the socioeconomic and environmental issues that will emerge a few decades hence.

4. The SCOPE study and the Ontario follow-up

As part of its preparation of a report entitled “Global Environmental Outlook 2000” (GEO-2000), UNEP invited SCOPE to undertake a global assessment of environmental issues that might emerge in the coming decades. The work began with the preparation of a questionnaire that was subsequently sent to many present and past members of SCOPE, to environmental managers and policy makers, to a few people from the business community, and (with the assistance of UNEP) to the global network of UNEP collaborating centers. The response rate was surprisingly high, and many of the comments were quite detailed. Two of the responses [from India (Chatterjee 1997) and from China] were subsequently published in national journals. The main results have been published in Munn et al. (1999).

At the request of the Ontario Ministry of the Environment, the three principals then focused their attention on the emerging issues that might affect Ontario in coming decades. Structured interviews with senior policy makers were carried out, as well as a workshop involving a group of scientists, each of whom was asked to write about three pages outlining what they believed to be a major emerging issue for Ontario (Munn 1999).

5. The array of issues that might emerge in coming decades

a. Introduction

The sponsors of the SCOPE–UNEP and of the Ontario studies initially thought that the main output of the assessments would consist of short priority lists of not more than 10 potential emerging issues. That hope was not realized. In the case of the global SCOPE study, respondents mentioned more than a hundred issues, while in the case of the Ontario workshop, the 19 participants who subsequently submitted three-page justifications for their choice of emerging issues produced statements on 19 separate issues, involving such varied subjects as fisheries, chemical contaminants, life styles and private choices, and the northward migration of Lyme disease into Ontario.

Much time was spent trying to categorize and prioritize the issues, but after some reflection in the context of the historical record, it was concluded that there was so much uncertainty, particularly with respect to socioeconomic futures, that nearly all of the issues ought to be kept under periodic review. However, the conclusion was reached that there are really only four major classes of emerging environmental issues (Munn et al. 1999):

1. Transformations of old issues; continually evolving, and in most cases broadening, in response to increasing scientific and technological knowledge and to changing socioeconomic, cultural, and environmental conditions;
2. Policy issues, the long-term environmental consequences of which may already be of concern;
3. Accidents waiting to happen, for example, chemical time bombs; and
4. Surprises, in the responses of ecosystems to new and different stresses, as well as in the nature of socioeconomic drivers of environmental change.

b. Emerging science-driven issues

The science-driven issues identified in the SCOPE–UNEP study included the following.

- Sustainable management of natural resources in an era of global change.
- Global nitrogen overload (Vitousek et al. 1997).
- Chemical time bombs (Stigliani et al. 1991).
- Oceanic flip-flops (Broecker 1997).
- Changes in food consumption habits.
- Epidemics.

- Biotechnology risks.
- Interactions among the global mega-issues (environment, population, development, trade, transport, and energy).
- Interactions among several issues (e.g., resolving one issue might worsen another) (Munn 1997).

These examples illustrate the wide variety of science-driven concerns about the future state of the environment. Of course the importance of each of these issues varies considerably around the world, and among scientists, policy makers, and the public.

c. *Emerging policy-driven issues*

Policy-driven environmental issues are historically of two main types.

1. Issues of concern to the public and to some “environmentalists,” and therefore to governments, but that in the opinion of scientists are trivial and that therefore distort the research priorities of research granting agencies. Examples include the concern in the early 1970s that by the year 2000, New York City would be under sea level and that the world’s phytoplankton would be poisoned by toxic substances, causing a significant depletion in atmospheric oxygen.
2. Issues of concern to scientists and to many environmentalists for which solutions are available but for which there is no social will to implement effective policies. Examples include the growth of suburbia and automobile populations; unhealthy diets in developed countries, and the increasing per capita water consumption, particularly in the semi-arid parts of Africa, constituting a real brake on development.

6. Research needs

In the course of the SCOPE–UNEP international study, a rather large number of research needs were identified (see Munn et al. 1999, p. 469, Box 4). And because the emerging issues themselves cannot be prioritized very effectively, so the research needs cannot be prioritized. This means that an adaptive approach to the selection of research topics to be emphasized is essential. The historical record shows that as a scientific field develops, research priorities often change. In addition, there are many historical examples of surprises (the stratospheric ozone hole in Antarctica, the

invasion of zebra mussels into the Great Lakes, the collapse of the Atlantic cod fisheries). Regular reviews of research priorities are therefore required.

a. *Research needs for science-driven emerging issues*

These included, for example, assessment of the environmental consequences of the coming post-fossil-fuel era, ecological engineering during a period of increasing global change, the behavior of nonlinear ecological and socioeconomic systems, and the effects of multiple stresses on ecological and social systems.

b. *Research needs for policy-driven emerging issues*

Among the research needs for policy-driven emerging issues are the following.

- How to operationalize the precautionary principle: This principle is nearly always mentioned in the opening declarations of intergovernmental environmental conference proceedings but is never followed up. However, the principle has now found its way into the body of the Biotechnology Protocol of the Biodiversity Convention, agreed to in Montreal in January 2000 over strenuous opposition.
- How to improve multi-issue assessments in cases where action to resolve one issue may create or worsen another.
- How to improve monitoring systems for obtaining early warning of emerging issues.
- How best to harmonize quantitative natural science data with qualitative social science data.
- In the last decade, another kind of policy-driven research need has emerged: how to determine the environmental aspects of various intergovernmental conventions, protocols, and agreements (“Trade and the Environment” is a hot topic at the moment. Other examples include the Kyoto Protocol and harmonization of the main U.N. environmental conventions).

7. Early warning indicators

a. *Early warning indicators of science-driven issues*

A major component to be included in a strategy for “managing” emerging environmental issues is the creation of early warning monitoring systems. One of the main difficulties in achieving this goal is the large amount

of noise surrounding environmental signals. Even when long historical time series are available, Pittock (1999) has pointed out that for policy applications,

Studies of the length of a data set necessary to detect a real change in the mean against a background of variability indicate that even if the change is real, it may need to have happened (and thus will have had impacts) for decades before it can be shown statistically to have occurred.

With this in mind, the best early warning indicators may often be obtained from measurements of the socioeconomic drivers of environmental change. As a simple example, a search for upward trends in the frequency and intensity of surface ozone episodes is more likely to be successful if based on trends in regional emissions of oxides of nitrogen from automobiles, power stations, and air conditioning equipment than from time series of ozone concentrations. In many such cases, of course, there will be need for well-formulated models of the system as a whole. Historical experience with the issues of stratospheric ozone depletion, acidic deposition, and climate warming shows that only when the fundamental processes involved are reasonably well understood can future trends be estimated with sufficient confidence to be used in policy applications.

In summary, five general criteria can be listed for use in the development of early warning monitoring systems.

- 1) Always use the ecosystem approach. For example, choose a watershed or other holistic scale, and include interactions and feedbacks among the system components.
- 2) Try to visualize surprises. Factor in a few not-impossible scenarios: if one of them were to happen, what kinds of data would provide the earliest possible warning?
- 3) Use simulation models when appropriate.
- 4) Use existing monitoring systems wherever possible but only after critical assessment of their relevance. (Considerable resources are required to create and operate monitoring systems so as much use as is feasible should be made of available data.)
- 5) Always use the adaptive approach. Particularly in the case of emerging issues, the design of an early warning monitoring system ought to be reviewed periodically (at least once every two years) by a group of environmental scientists and stakeholders.

b. Early-warning indicators of policy-driven issues

This is a field that has hardly been explored as yet, requiring as it does the active collaboration of natural and social scientists.

8. Concluding remarks

As pointed out earlier, an important characteristic of emerging environmental issues in the twenty-first century is that they are largely transformations of old issues, continually evolving and broadening. Several decades ago, climate change was a subject to be studied by climatologists. Later, oceanographers were added to the team, then glaciologists, and finally ecologists. Now the door is opening for engineers, health scientists, and social scientists. The International Human Dimensions of Global Change Program is collaborating more closely with the IGBP and the World Climate Research Programme and is mounting international projects examining land use change, industrial transformations, environmental security and the institutional dimensions of global change. As pointed out by Jasanoff et al. (1997),

The physical sustainability of the biosphere is now seen to be inseparably bound up with issues of economic development, social equity, and international peace and security.

A final comment to be made is that one way of successfully predicting the future is to try and create it. Because of the failure of detailed long-term planning in the Soviet Union and elsewhere, we have recently moved into a nonstrategy of incremental improvement of the present. There may still be room for a middle ground, including, for example, some broad envisaging of alternative sustainable futures that could serve as a framework within which desirable emerging issues could be promoted while at the same decreasing the probability that undesirable ones might occur. This has been called the “how-do-we-get-there-from-here” approach.

References

- Broecker, W. S., 1997: Thermohaline circulation, the Achilles heel of our climate system: Will man-made CO₂ upset the current balance? *Science*, **278**, 1582–1588.
- Chatterjee, K., 1997: Emerging environmental issues. *Develop. Alt.*, **7** (10), 13–14.

- ECA, 1995: Ensuring prosperity: Implementing sustainable development. Report of the Future Environmental Directions for Alberta Task Force, 112 pp. [Available from Alberta Environment, Information Centre, Main Floor, 9920-108 St., Edmonton, AB T5K 2M4, Canada.]
- Farman, J. C., B. G. Gardiner, and J. D. Shanklin, 1985: Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature*, **315**, 207–210.
- Glenn, J. G., and T. J. Gordon, Eds., 1997: *State of the Future: Implications for Action Today*. American Council for the United National University, 202 pp.
- HARC, 1996: Houston Environment 1995. Houston Advanced Research Center, Houston, TX. [Available online <http://www.harc.edu/foresight.html>.]
- Jasanoff, S., and Coauthors, 1997: Conversations with the community: AAAS at the millennium. *Science*, **278**, 2066–2067.
- Molina, M. J., and F. S. Rowland, 1974: Stratospheric sink for chlorofluoro-methanes: Chlorine atom catalyzed destruction of ozone. *Nature*, **249**, 810–814.
- Munn, R. E., Ed., 1997: Proceedings of workshop on atmospheric change in Canada: Assessing the whole as well as the parts. *Env. Mon. Assess.*, **46**, 1–190.
- Munn, T., 1999: *Emerging environmental issues in Ontario*. *Env. Monograph*, No. 15, Institute for Environmental Studies, University of Toronto, 70 pp.
- , P. Timmerman, and A. Whyte, 1999: Emerging environmental issues: A global perspective. *Ambio*, **28**, 464–467.
- NISTEP, cited 1997: Sixth technology forecast report: Future technology in Japan toward the year 2025. National Institute of Science and Technology Policy Report. [Available online at www.nistep.go.jp/achiev/report52-e/top.htm].
- Pittock, A. B., 1999: The question of significance. *Nature*, **397**, 657–658.
- Schellnhuber, H. J., 1999: “Earth system” analysis and the second Copernicum revolution. *Nature*, **404** (Suppl.), c19–c23.
- Stigliani, W. M., P. Dolman, W. Salomons, R. Schulin, G. R. B. Smidt, and E. A. T. M. van der Zee, 1991: Chemical time bombs: Predicting the unpredictable. *Environment*, **33**, 5–9, 26–30.
- Svedin, U., and B. Aniansson, Eds., 1987: *Surprising futures*. Swedish Council for Planning and Coordination of Research, Stockholm, Sweden, 128 pp. [Available from Swedish Council for Planning and Coordination of Research, S-113 85, Stockholm, Sweden.]
- Vitousek, P. M., J. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger, and D. Tilman, 1996: Influence of nitrogen loading and species composition on the carbon balance of grasslands. *Ecol. Issues*, **1**, 1–15.