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INTRODUCTION

This report contains the recommendations of more than 450 scientists and decisionmakers who participated in the first National Conference on Science, Policy and the Environment on December 7 and 8, 2000. The conference was sponsored by the National Council for Science and the Environment and was held at the National Academy of Sciences in Washington, DC.

The conferees included individuals from more than 45 states and the District of Columbia, as well as Canadians and Europeans. They came from a broad range of disciplines and perspectives in the natural sciences, social sciences, and engineering (from agriculture to zoology), as well as the information technology and policy sectors. Among those participating were:

- 200 academics, including administrators, faculty, staff and students from a diverse set of universities and colleges
- 100 government employees, including Democratic and Republican elected officials, scientists, administrators, and managers at the local, state, tribal, and federal levels
- 50 representatives of environmental and community organizations working at local, state, regional, national, and international levels
- 25 individuals representing a diverse set of private businesses
- 60 self-identified as "others," including journalists, school teachers, and representatives of scientific organizations.

The overarching theme of the recommendations is the need for this nation and the world community to achieve a level of sustainability that integrates three basic elements: economic security, ecological integrity, and social equity. The concept of sustainability is typically viewed as having simultaneous and interdependent scientific, economic, social, political, psychological, ecological, ethical, and technical dimensions. In this regard it is noted that both the conference agenda and its resulting recommendations are consistent with a recent Council of Scientific Society Presidents' policy statement on achieving a sustainable future:

> *As a national priority, we must make public investments in all areas of fundamental research that can lead to more sustainable systems. The nation's top political and corporate leaders, working closely with scientists, must develop and implement an action plan to achieve a sustainable future that involves all levels of government, academia, NGOs, and the private sector.**

*see www.science-presidents.org for the full statement

purpose and goals

The unifying focus of the conference was on setting a well-conceived agenda for science for environmental decisionmaking in the 21st Century that is built on a new interdisciplinary "science of sustainability."* The organizing principle used by the Council in developing the conference mission was that stakeholder-informed science is the most powerful means to building consensus for solving the serious environmental problems facing the United States and the world community.

The highlight of the conference—which included formal presentations by some of the nation's most eminent specialists on environmental research and policymaking (Appendix 1)—was the inauguration of the John H. Chafee Memorial Lecture on Science and the Environment. During his 23 years of service in the United States Senate, the late Senator John H. Chafee demonstrated how much a passionate commitment to environmental protection and a civil bipartisan approach to science-based policymaking could contribute to achieving a sustainable future.

Nobel Laureates F. Sherwood Rowland and Mario J. Molina delivered the first lecture jointly. They were the leading scientists in what has often been referred to as "the world's biggest success story to date of using science to resolve an environmental problem." In the lecture, the two scientists described their discovery that chlorofluorocarbons cause stratospheric ozone depletion and their subsequent efforts to use this scientific understanding to encourage policies that would reverse the problem. (The lecture will be published and made available through the Council.)

The logic of the organizers in devoting a major portion of the conference program to breakout sessions on 14 specific topics was that by doing so participants could provide the most immediate and effective assistance to decisionmakers in the new Administration and the Congress. They accomplished this in the working groups by identifying: (1) critical knowledge gaps where more and better science is needed, and (2) critical communication gaps that seriously impede decisionmaking efforts by policymakers.

*See *Our Common Journey: A Transition Toward Sustainability*, Board on Sustainable Development, National Research Council, 1999.
See also Appendix 5

Each breakout session was charged with generating a brief set of recommendations for improving the scientific basis for decisionmaking within their given topic area. Participants were told that the recommendations could be addressed to the government as a whole and/or to its specific agencies and that they were not expected to be consensus views.

The Council also suggested that the recommendations focus specifically on science needs and not on what the environmental policy of the United States should be. It was further requested that the recommendations identify either: (1) scientific information needed for environmental decisionmaking, or (2) methods to connect science with environmental decisionmakers.

The recommendations submitted by each breakout session represent the general (but not necessarily consensus) views of participants attending that session. A list of each session's chairperson, facilitator, and invited speakers is included as Appendix 2. Numbers used are for organizational purposes, not prioritization.

A list of conference participants appears in Appendix 4. The listing of a name does not imply agreement with all of the recommendations contained in the report. Affiliations are listed for identification purposes only.

The National Council for Science and the Environment expresses its most sincere gratitude to all of the participants in the conference and to all of those who will consider these recommendations and work toward their adoption and effective implementation. In particular, the Council wants to thank those 100 or so individuals who prepared background material and papers, who presented formal remarks to the conference, and who chaired, facilitated, and prepared the recommendations for each of the breakout sessions. Their names appear in Appendix 2.

summary of recommendations

Although each breakout session was independent, when the recommendations are viewed as a whole a notable number of similarities and common themes emerge in the types of problems identified by the groups as well as in their suggested solutions. Among these:

1. The breadth, depth, and diversity of the scientific specialties involved in successful environmental decisionmaking make **interdisciplinary** and **multidisciplinary** approaches essential.

2. Serious voids in scientific knowledge make resolution of current environmental problems and prevention of any future problems extremely difficult. Significant **investment** in environmental science and engineering is needed.

3. The number of governmental, quasi-governmental, and non-governmental organizations involved in environmental decisionmaking increases the likelihood of serious voids or duplications in necessary programs. Identifying and **coordinating** both the missions and efforts undertaken by these organizations was identified as a top priority.

4. There is a crucial need for periodic **knowledge assessments** that can provide scientists and policymakers with reliable and timely "state of the science" reports on the environment as a whole as well as on particular topics. Such assessments will require coordinated, multi-agency environmental tracking, monitoring, and inventory programs.

   A new and separate entity–such as a "Bureau of Environmental Statistics"–could provide leadership and information that is both scientifically and politically credible.

5. Sound environmental decisionmaking is dependent on an effective **interface between scientists and policymakers** based on reliable and timely "translation" of information and views between the two communities.

6. A **national environmental information infrastructure** that will support intensified public information programs and environmental education and training initiatives (K-Adult) is fundamental to the success of such "translation" efforts.

7. Science-based **education** about the environment is required at every level of society if the general public and their elected officials are to make informed, effective, and timely decisions.

8. The **integration** of environmental knowledge, assessments, research, information, communication, and education is vital if our society is to achieve a requisite level of sustainability.

The National Council for Science and the Environment will communicate these recommendations to Administration and Congressional policymakers and will work with the various stakeholders represented at the conference to encourage their adoption and effective implementation.

The Council also has developed an electronic bulletin board where all interested individuals can discuss these recommendations: www.ncseonline.org/policybb.htm

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Environmental biodiversity and ecosystem health

Maintaining diverse, productive and healthy ecosystems necessitates a fundamental change in management strategy, from single-species to whole ecosystem management. The challenge is to optimize the long-term value of ecosystems to humans while protecting biological diversity and ecological processes. Over the past decade, terms such as conservation biology, concepts of biodiversity, ecosystem health, and landscape ecology have been refined by scientists and have become a more common part of the public vernacular. In turn, as society has become more concerned about conserving ecosystems and their associated species, resource management agencies have begun to shift scientific inquiries to the landscape level. There is considerable need for science to better understand biodiversity and ecosystem processes; how humans affect and are affected by these processes; and how to communicate this understanding to natural resource managers and policymakers.

RECOMMENDATIONS

1. Knowledge of Biodiversity and Ecosystems
The federal government should develop and support programs that:

- increase the capacity to conduct scientific research in key disciplines including: taxonomy, systematics, ecosystem and landscape ecology
- build capacity for resource science and management internationally, as well as nationally
- increase efforts for interdisciplinary synthesis of knowledge
- increase understanding of linkages between biodiversity, ecosystem productivity, and sustainable natural resource management.

The federal government should sustain and coordinate a multi-agency program to:

- inventory biological resources with a ten-fold funding increase over current levels
- monitor biodiversity, including dissemination of information on the state of the environment in a "report card" format (possibly through a new Bureau of Environmental Statistics).

2. Landscape Science: Geographic Scale and Physical and Political Boundaries
The federal government should develop, sustain and coordinate a multi-agency, cross-sectoral program to:

- better understand how. ecosystems are connected across physical and political boundaries
- increase the capacity to manage and coordinate across political boundaries
- synthesize and coordinate place-based research, including more assessments at a regional scale.

3. Education and Public Awareness
The federal government should develop, sustain and coordinate a multi-agency program in disciplinary and interdisciplinary education and training about natural resources, including public education, K-12 and higher education, and professional development.

4. Translation of Knowledge Between Science and Policy
The federal government should develop, sustain and coordinate a multi-agency program with the goal of providing more effective application and translation of science into management that would:

- increase the interface between policymakers and researchers in design of science programs
- increase scientific input at all stages of policy process
- add more scientists in decisionmaker positions
- develop of a cadre of science-policy translators.

The federal government should sustain and coordinate a multi-agency program directed towards better understanding of the human dimensions (causes and consequences) of environmental change and biodiversity.

5. Information Management and Synthesis
The National Academy of Sciences should study the methods and associated standards used to assess and synthesize the state of knowledge of biodiversity. There should be a cross-government inventory of biodiversity and ecosystem databases and research programs with a goal of increased efficiency and compatibility and decreased duplication.

6. Stakeholder Participation
All of these programs should include meaningful and sustained mechanisms to incorporate perspectives of diverse stakeholders, particularly those outside the federal government.

environmental implications of biotechnology

Scientific and public understanding of the environmental implications posed by biotechnology, particularly in the agricultural sector, have not kept up with the dramatic pace of the development and use of genetically engineered organisms. Research on the ecological effects of biotechnology should be increased significantly. The number of stakeholders in the discussion must be increased, and communication of scientific information about the issue must be both improved and increased.

RECOMMENDATIONS

1. Knowledge Assessment
The National Academy of Sciences (NAS) should perform a "knowledge assessment" of what is known with what degrees of certainty about the environmental implications (positive and negative) of biotechnology. This should inform a domestic and international dialogue that involves a broad range of stakeholders.

2. Public and Media Understanding
The President (through the Office of Science and Technology Policy) should announce a set of science initiatives that increase public information and media understanding of biotechnology. This effort should include both the establishment of a neutral clearinghouse for information about biotechnology and regular reports to Congress.

3. Research on Environmental Implications
The National Science Foundation (NSF) should create an initiative to fund multidisciplinary research and training to better understand the environmental implications of biotechnology. NSF should involve other federal agencies to provide joint funding.

4. Research on Non-target Effects
The National Institute of Environmental Health Sciences (NIEHS) should provide funding for natural and social science studies on effects of biotechnology on non-target organisms.

5. Benefits in and beyond Agriculture
The U.S. Department of Agriculture (USDA) and the National Science Foundation (NSF) should create a joint funding initiative to assess benefits in and beyond the agricultural setting, including, for example, those associated with bioremediation

Specific Research Needs In Biotechnology
(With A Particular Focus On Those Related To Agriculture)

1. Multidisciplinary study of environmental implications and multi-scalar consequences

2. Studies of all—not only transgenic—crops

3. Integration and synthesis of research findings

4. Understanding of the unintended consequences of biotechnology, including effects of genetically modified organisms (GMOs) on non-target species, such as organic crops, wild plants and pollinators

5. Studies of cross-fertilization and cross-hybridization of crops

6. Research in bioinformatics and its application to agriculture as well as research on predicting the impacts of bioinformatics on biotechnology and the environment

7. Research on benefits, including comparisons of effects of GMOs with those of the products or processes for which GMOs are being substituted

8. Risk assessment including field-testing of GMOs before they are approved, to assess risk on wild plants and pollinators, as well as evaluation of impacts after a period of use

9. Assessment of how environmental impacts of biotechnology are evaluated

10. Social science research into the issues surrounding biotechnology that would identify the kinds of questions currently being asked and the reasons why these questions are being posed; how public perceptions are formed; and the implications of economic forces, including how industry needs affect research agendas

11. Study of the ethical implications of biotechnology

12. Analysis of the needs of agricultural producers and consumers

13. Development of defensible and workable Insect Resistance Management (IRM) plans

14. Study of nonagricultural issues, including: medical and industrial uses and environmental remediation.

Environmental

environmental indicators

In order to answer questions about the current condition of natural resources and determine long term trends, monitoring programs have been established to assess the condition of our estuaries, streams, forests, and other resources. The many reasons for undertaking such environmental quality assessments include: protecting human health; maintaining the integrity of ecosystems; improving understanding of the functioning of disturbed and undisturbed systems; and identifying the most appropriate indicators for describing the status and trends of environmental conditions. This knowledge can also be used to guide control measures and suggest remedial actions to improve environmental quality.

Successfully measuring the state of the environment requires measurements of reliable, sensitive, and interpretable indicators of condition. Indicators need to be understandable, quantifiable, and broadly applicable. The indicators should relate directly to characteristics, uses or sustainability of the particular system. Indicators can be biological (including biochemical, cellular, organismal, population, community or ecosystem level), chemical, physical, and social measurements. Indices can be created that integrate several individual measurements to provide a single number that represents the condition of a resource.

RECOMMENDATIONS

Congress and the Administration should direct agencies to invest in the development, use, and reporting of environmental indicators that are:

- understandable to the public and to policymakers
- connected to policy and management goals and measured against defined targets
- meaningful across varying temporal and spatial scales and take response time and sensitivity into account when measured against the needs of decisionmakers
- aimed at filling gaps in data, analysis, and reporting among existing indicators, and that place more emphasis on ecosystem-level functions among new indicators
- targeted toward defined environmental health goals
- incorporated into integrative models showing feedback among indicators (such models display predictive scenarios, and incorporate degrees of certainty)
- able to facilitate simulation, which can be useful in examining relationships among indicators and the relationships between indicators and the environmental systems that they represent
- part of long-term programs with sustained funding that involve comparable analytical methods across indicators.

Any monitoring programs conducted by citizens should be required to use standardized methods that are consistent with and linked with the type of government and scientific monitoring efforts described above.

federal government structure

The fragmented jurisdictions among U.S. Federal agencies charged with environmental stewardship compound difficulties in coordinating environmental research and in communicating scientific results to decisionmakers and the public. Certain, relatively minor, changes in governmental institutions could significantly improve efficiency and communication among scientists and between scientists and decisionmakers.

GENERAL RECOMMENDATIONS

1. Synthesis
Science needs to be synthesized and translated for policy makers, in order to help them make decisions in the face of conflicting or incomplete scientific information.

2. Education
Scientists and policymakers need to be educated broadly and must understand each other's disciplines and perspectives.

3. Coordination
The coordination of scientific research needs to be improved so that it is appropriate, timely, and relevant to the policy being developed.

4. Relevance
Research needs to meet the needs of decisionmakers. There should be periodic scientific analysis of the effectiveness of policy actions in reaching stated goals.

5. Infrastructure
The infrastructure for environmental research should be strengthened. New entities that will focus specifically on science for environmental decisionmaking need to be created.

SPECIFIC RECOMMENDATIONS

1. The government should develop institutions and structures to:
- help policymakers and scientists to interact
- help scientists to anticipate the needs of agency decisionmakers
- identify and analyze short-term and long-term information needs.

2. Federal science and resource management agencies need "policy centers" that will:
- assess the policy implications of the science
- conduct peer review of proposed policies
- conduct post-implementation evaluation of policies.

The Centers should include environmental, economic, and social information and expertise, and involve scientists from outside the agency.

3. Congress should establish a Joint Committee on the Environment (analogous to the Joint Economic Committee).

4. Scientists need training in environmental policy, and policymakers need training in understanding science. The President should require all appointees to attend science workshops.

5. The government should have formal processes in place through which to develop consensus on policy recommendations based on the current state of knowledge (modeled on the National Institutes of Health consensus panel process). This could possibly be one function of a resurrected Office of Technology Assessment (OTA), which is also recommended.

6. Congress should resurrect the Office of Technology Assessment.

7. Congress should create a Bureau of Environmental Statistics (analogous to the Bureau of Labor Statistics).

global environmental change

Human beings are now making profound changes to the environment on a global scale by altering landscapes, the atmosphere, and the oceans. The science aimed at understanding these changes has grown from research, primarily in the physical sciences, aimed at understanding climate change towards a synthetic global change science that also incorporates ecological and social sciences. Global change science is "focused on the accurate characterization of the vulnerability and resilience of natural and managed ecosystems and human society to global change." (Our Changing Planet: the FY 2001 U.S. Global Change Research Program). Much of the research in this area is conducted under the auspices of the multi-agency U.S. Global Change Research Program (USGCRP). Because there are major policy implications of this research, new mechanisms are needed to provide "useful scientific products that contribute to the information needs of decisionmakers."

The importance and popularity of this topic led to the formation of two concurrent and independent sections. Each section (A and B) developed its own set of recommendations.

Section A: Global Environmental Change

RECOMMENDATIONS

1. Interdisciplinary Decisionmaking Framework for Science
The Administration should more broadly support "Science for Sound Decision-Making" regimes by establishing a multi-agency and multi-disciplinary research initiative on human responses to global environmental threats.

2. Environmental Indicator Service
The Administration should establish an Environmental Indicator Service that would:

- include a monitoring system of key indicators
- develop and use models for environmental forecasting
- conduct large-scale experiments within a new regional network proposed as Terrestrial Environmental Research Facilities (TERF)
- communicate ongoing information about the status of the environment
- develop and implement a top-down strategy for directing research to inform decisionmaking.

3. Communication of Science
The Administration and Congress should fund programs that provide the effective communication of science to the public, journalists, funders and decisionmakers.

4. Environmental Education (K-Graduate)
Environmental Education programs should:

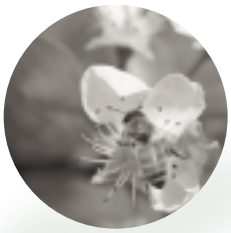
- develop flexible, fun, and relevant teaching material; promote teacher education through involvement in research, incentives and standards
- teach science as a process.

5. A Broad Global Environmental Change Program
The U.S. Global Change Research Program (USGCRP) should:

- examine the human causes and consequences of global change
- have the Office of Science and Technology Policy (OSTP) ensure that the CHIEF initiative of the National Research Council (NRC) is further defined and then implemented by a suite of agencies
- continue along directions defined by the National Assessment for the United States Global Change Research Program (USGCRP).

6. Relationship between Global, Regional, and Local Change
The U.S. Global Change Research Program should:

- develop an understanding of how global change plays out at regional and local scales
- consider how human action at local and regional scales affects global change.



Section B: Global Environmental Change

RECOMMENDATIONS

1. Infrastructure for National Assessments
The United States Global Change Research Program (USGCRP) should establish a permanent infrastructure for national assessments, including secretariat functions with permanent scientific staff and outreach capability.

2. Extreme Climate Effects
The USGCRP should expand research programs at regional levels on the probability and consequences of extreme climate effects.

3. Interdisciplinary Research
The National Science Foundation (NSF) should enhance incentives for interdisciplinary research integrating natural and social sciences.

4. Land Use, Land-use Change, and Forestry
Congress should direct and fund the Department of Agriculture (USDA), the Department of Interior (DOI), and other relevant departments and agencies to develop a highly integrated, multi-agency program for the study of land use, land-use change, and forest management.

5. Communication Plan
The scientific community and end-users should develop a communication plan outlining criteria for a delivery system through which scientific information may be presented to the public and policy makers in a digestible form.

6. Observational and Research Efforts
Federal agencies need to fund long-term (50-100 years) observational and research efforts through endowments established by Congress.

7. Teacher Training
The NSF and the Department of Energy (DOE) should fund teacher-training programs in global environmental change that involve international components.

8. Environmental Vulnerability Index
The National Institutes of Health (NIH), the U.S. Agency for International Development (USAID), and NSF should fund the development of an "Environmental Vulnerability Index" that is relevant to human populations, and comprehensive in scope, integrating major human activities that degrade local, regional, and global environments.

human health and the environment

According to the Pew Environmental Health Commission, 90% of voters believe that the environment plays a significant role in health. Infectious diseases and other environmentally-caused diseases, in particular, are continually creating new health burdens. Yet, environmental science and environmental health science communities are too frequently independent of one another, funded by different agencies and consisting of different researchers. If these disciplines fail to push ahead collectively with further research and prevention, the many burdens of environmentally-influenced illness imposed upon our society may become even heavier.

RECOMMENDATIONS

Overarching Objectives

1. Increase the Science Base
The Administration and Congress should provide funding in order to:
- increase the science base in environmental health
- better inform policy
- protect the health of humans and the environment.

This is a time of great scientific opportunity, in view of new genomic and analytic approaches. Investing in funding in the next four years will have a major and positive impact on health and the environment.

2. Multidisciplinary Research Programs
The Administration should integrate efforts in environmental science and environmental health science via:
- development of multidisciplinary research programs that can be supported by multiple agencies and multiple stakeholders (federal, state, non-governmental, industry, etc.)
- supporting research program infrastructure and training for the next generation of investigators
- establishing cross-disciplinary centers of excellence in many institutions.

3. Coordinated Environmental Health Science Policy and Information Programs
The Administration should coordinate environmental health science policy and information programs at the highest levels in the Public Health Service (PHS), EPA, DOE, DOD, etc.

These departments and agencies should provide information about environmental health exposures and hazards (including information generated by the private sector).

Specific Needs

4. Public Need for Information
Congress should fund additional research on how to identify and satisfy the public's needs for information about environmental health.

5. National Environmental Health Tracking System
The Administration should create a national environmental health tracking system to monitor rates of chronic disease and exposures in the U.S. population in order to inform public health and policy and to benchmark progress.

6. Monitoring of Human Exposures
Congress should fund developmental research and monitoring of human exposures including:
- the use of exposure measures for risk assessment
- documentation of exposures to mixtures of pollutants
- examination of exposure patterns in specific populations
- the impact of both acute and chronic exposure
- the potential for gene-environment interactions.

7. Health Benefits of the Natural Environment
A partnership between health agencies and environmental agencies should study the health benefits of the natural environment. Both physical and psychological health benefits should be addressed.

8. Health Implications of Global Changes and Ecological Trends
The Administration should create programs to study the health implications of global changes and ecological trends including:
- climate change, to understand trends and adaptive/mitigation strategies
- links between environment and emerging/reemerging diseases (i.e., West Nile virus, red tide)
- links between loss of ecosystem integrity and biodiversity and health impact, including cultural impacts
- links between energy policies and use (e.g. utilities and transportation) and health.

9. Environmental Impacts on Children
The Administration should continue and expand efforts to understand and learn how to mitigate environmental impacts on children including:
- conducting national longitudinal cohort studies
- establishing centers of excellence in children's environmental health
- coordinating efforts on asthma, developmental disabilities and childhood cancer.

10. Environmental Health Disparities
The Administration should develop research initiatives that are aimed at understanding the role of environmental health disparities between different racial/ethnic and economic groups in the U.S. and internationally. Such initiatives would focus on:
- the impacts in specific groups (e.g. metals and persistent pollutant exposures to Alaskan natives)
- the development of interventions to prevent those impacts.

11. Environmental Genomics/Proteinomics
The Administration should initiate a federal effort to establish and coordinate centers for environmental genomics and proteinomics that would:
- include social and ethical issues as well as genetics, statistics and information technology
- make all information available online to researchers.

12. Health Impacts of the Built Environment
The Administration should establish a research program on the health impacts of the built environment, with broad participation by health, housing, transportation, and environmental research agencies and non-federal partners that would address such issues as urban ecology, urban sprawl (land use and transportation planning), and buildings (homes and institutions, including green buildings).

Environmental

higher education

The concept of sustainability can be a unifying principle for a wide range of interdisciplinary and multidisciplinary problems and solutions. It can serve to capture the interests and imaginations of students, faculty, administrators and governing boards and can vividly encapsulate the greater needs of human society. There are many challenges and opportunities with respect to the understanding and application of sustainability concepts at institutions of higher education.

RECOMMENDATIONS

Significant additional support is required for curriculum development, operations, and campus/community partnerships in the environmental education arena. The National Science Foundation (NSF) should focus its increased support on the high-priority areas listed below. As these are consistent with the environmental objectives of other federal, state and local agencies, as well as the private sector, all of these entities should be brought in as partners to support this agenda.

1. Curriculum Development, Graduate Studies, and Fellowships

To better understand the concept of sustainability and to foster faculty and student involvement, funding should be increased for curriculum development, graduates studies, and fellowships.

This funding should:

- encourage development and evaluation of interdisciplinary curricula and support their dissemination
- provide opportunities for students to learn off campus in local communities.

2. Campus Community Partnerships

Partnerships between campuses and communities (including different professions, social groups and minority groups) should be established in order to:

- enable students to be involved in service-learning and community partnerships
- recruit minority students into environmental fields and programs, including through development of programs targeted to faculty and students at minority institutions
- encourage collaborations between institutions of higher education and different segments of communities
- support culturally-sensitive transfer of knowledge among people in different societies.

3. Training and Research Projects

NSF should fund training and research projects on sustainability and its integration into different aspects of university life by:

- providing "bite-sized" grants (grants for smaller projects on the order of $10,000 each)
- funding graduate student traineeships and fellowships in areas relating to sustainability
- funding research on how to measure sustainability.

information systems

Environmental information has been defined as "…the process that transfers data and information from its source to users in any field of knowledge or activity applicable to environmental problem solving." Yet, like so many other types of information, environmental information is overburdened by a glut of data and a dearth of mechanisms with which to transmit high quality information from supplier to user.

RECOMMENDATIONS

The United States should develop a National Environmental Information Infrastructure (NEII) that crosses scientific domains (i.e., applied, physical, information, natural and social sciences, engineering), sectors of the economy (i.e., private, academic, government), and lines of work (i.e., research, education, advocacy, communication, information).

1. National Environmental Information Infrastructure
The NEII should be an open architecture for network development, with appropriate computer power [data, information, and knowledge management], and user interface.

2. Ensure Data
The federal government and its partners should work to ensure data (information) availability, quality, and preservation through this architecture.

3. Tool Development
The federal government should promote the development of tools to make information available to a multiplicity of users at varying geospatial scales and time frames.

4. Data Evaluation
Creation of the NEII should begin with a comprehensive analysis to evaluate the many data and information repositories and data support systems at global/international, national/federal, state/provincial, and local levels. They should be evaluated in regard to:

- acquisition of data (and information)
- management of data
- integration and analyses of data
- dissemination of data
- examination of cross-cutting issues to examine organizational roles of data producers, providers, and users.

5. Multi-Stakeholder Advisory Board
There should be a multi-stakeholder advisory board (e.g., data producers/providers, data/information managers, data/database vendors/providers, librarians and other information providers, and various user communities) to examine the creation of a central, comprehensive environmental information infrastructure that would:

- coordinate efforts across scientific domains, industries, and institutions
- provide access to and communication of data and information for multiple categories of end users
- promote the use of environmental indicators and methods of advanced environmental accounting
- emphasize the need for a U.S. commitment to support environmental data and information systems and management
- identify environmental decision areas that currently lack robust supporting data and information resources
- examine educational opportunities and training in scientific, policy, and information technology (including librarians)
- examine policies for discussion of publication, dissemination, and "digestion" of data and information
- identify and network among repositories of human and organizational expertise and resources.

6. Outcome
Completion of these tasks would serve to:

- define an environmental information infrastructure that is timely, adequate, and comprehensive
- address the need to develop services, products,and programs that are efficient, economic, and equitable.

invasive species

Invasive species are non-native (or 'alien') species that have become established where they did not previously occur and have been found to cause harm to the environment, the economy and, in some cases, to human health. Economists estimate that invasive species cost the nation $138 billion annually, including $72 billion to U.S. agriculture alone. These figures do not include the ecological impacts caused by invasive species, which are considerable.

In 1999, President Clinton issued Executive Order 13112 establishing the National Invasive Species Council (NISC), which is co-chaired by the Secretaries of the Departments of the Interior, Agriculture, and Commerce. The Council established the Invasive Species Advisory Committee (ISAC), a non-federal group of experts and stakeholders that provides advice and stakeholder input to the Council. The NISC sponsored and facilitated this breakout session.

GENERAL RECOMMENDATIONS

1. Integrated and Comprehensive Planning
Because science-based responses are only one aspect of a full suite of response measures (i.e. education, policy making) to the problems posed by invasive species, an effective approach to dealing with invasive species requires integrated and comprehensive planning that spans the gamut from invasion to elimination/control to restoration/recovery.

2. Multi-Agency Initiative
The Federal approach to invasive species needs to be a multi-agency initiative because most of the cabinet-level departments and many agencies are involved and have roles to play. Because many research programs have proven to be more effective when they cut across agency boundaries, it is important that relevant agencies should look at and apply existing models of interagency cooperation.

3. Interdisciplinary Research
Research on all aspects of the invasive species problem needs to be interdisciplinary. Existing funding agencies should establish new programs to facilitate interdisciplinary research, giving special attention to research that falls between the "disciplinary cracks" (i.e. not fully economics or ecology, but rather an interface of the two).

4. The Role of Humans
The dialogue on invasive species should articulate clearly the role of humans in contributing to and being affected by invasions of non-native organisms.

Environmental

SPECIFIC RECOMMENDATIONS

1. In order to inform rapid response capabilities and long-term management needs, the federal government should support existing programs and establish new programs to quantitatively assess ecosystems before, during, and after biological invasions.

2. Research to identify invasive pathogens and vectors needs to be expanded, as does research on the taxonomy, systematics, and technologies needed to detect and respond rapidly to invasions of these organisms.

3. Research and development on methods and technologies of control and elimination needs to be increased, with specific emphasis on finding solutions that are environmentally sound.

4. To better inform economic and policy decisions, there is a significant need to continue existing research and initiate new research to:

- determine the vulnerability of ecosystems to invasion and the role and effects of multiple stress factors
- understand the human dimensions (causes and consequences) of invasive species
- determine the ways and degrees in which invasive species disrupt ecosystem services
- identify:
  - the industries and other social forces responsible for facilitating the major pathways of invasion
  - the actions (scientific, technological, policy, etc.) through which they can minimize invasion
  - the ways to inform them of these options
  - how to use voluntary incentives and/or policy measures to ensure effective response.

The breakout session fully endorsed the research, development, and analysis recommendations put forward by the Committee on Environment and Natural Resources (CENR), National Invasive Species Council (NISC), and the Global Invasive Species Programme (GISP), with one exception: deletion of the word "faster" from the NISC recommendation to "develop proposals for faster development, testing, transfer of safe biocontrol."

Environmental

pollution prevention/waste management

In the decade following the passage of the Pollution Prevention Act in 1990, myriad government and industry programs have been developed to prevent pollution. At the heart of these programs has been the EPA's emphasis on source reduction, based on the presumptions that (1) pollution control would have already been addressed by other regulations, and (2) that most pollution was better controlled at the source. EPA defines pollution prevention as source reduction: preventing or reducing waste where it originates, at the source – including practices that conserve natural resources by reducing or eliminating pollutants through increased efficiency in the use of raw materials, energy, water, and land.

Now a new multidisciplinary scientific field referred to as "Industrial Ecology" has evolved, using new tools such as multimedia Life Cycle Analyses (LCA) that facilitate systems that incorporate environmental considerations into their design. Such systems minimize environmental impact, and thereby prevent pollution at its source. LCAs provide a comparative tool that would help one to evaluate projects and product systems across the life cycle (i.e., raw material extraction, manufacturing, use, recycle/disposal) on the basis of material and energy usage and, later, on the basis of environmental impacts. Many leading industries have already begun to evaluate projects, proposed improvements, and even product systems on the basis of LCA.

RECOMMENDATIONS

1. Technology Research and Development
DOE, DOD, EPA, and DOC should promote the development of new pollution prevention and waste management technologies through targeted research funding.

2. Behavioral Aspects of Pollution Prevention
NSF and EPA should fund research into the individual and organizational behavioral aspects of pollution prevention and waste minimization.

3. Material Flows
There should be more data collection and analysis throughout the life cycle of products and processes, particularly material flows and toxics, using data collected through regulatory methods (EPA, Congressional action) and industrial disclosure (DOC and USGS).

4. Pollution Prevention Assessment Tools
EPA, NSF and states should collaboratively document and develop methods to assess the impacts of pollution prevention.

5. Social Dimensions of Pollution Prevention
- EPA, NIST, NSF, and the Consumer Product Safety Commission should conduct and fund research into product labeling, including its format, content, effectiveness, and methods of implementation and other methods of raising public awareness.
- NSF and EPA should conduct and fund research to better understand and improve stakeholder processes.

6. Education and Outreach
- There should be federal funding for education and outreach on implementation support through cooperative extension, universities and local entities.
- EPA, NSF and cooperating universities should establish and lead an international panel on multidisciplinary education and curriculum development on pollution prevention.

population and the environment

Although many scientists and laypersons recognize that increased human population is often a major cause of decreased environmental quality and a subsequent diminished quality of life, the scientific understanding of the details of these linkages is far from perfect. Linkages between population and the environment need to be considered with respect to population impacts on environment and environmental impacts on population. Linkages should be examined in urban, suburban and rural environments and in countries with various levels of development. Natural resource and technology/pollution issues are both relevant. Linkages at the global, country and regional levels have been and should be further considered.

RECOMMENDATIONS

1. Federal Leadership: An Interagency Panel on Population and Environment Science

An interagency Panel on Population and Environment Science should be established within the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR). It should be charged with developing and coordinating a population and environment science initiative that brings together all federal agencies supporting environmental R&D in order to integrate population issues into their programs. It should not be involved in population policy.

2. Agenda-setting, Communication, and Integration

- The federal government should establish mechanisms to facilitate communication and agenda-setting among diverse scientific communities, policymakers and the public about the linkages among population and environmental issues.
- Agencies should provide funding for sustained interactions between experts from the population research community and the natural science community.
- The National Research Council should form a multidisciplinary panel to review the status of science on the connections between human populations and the environment, and make recommendations on future research and mechanisms for communication.
- Agencies such as the National Institutes of Health and the National Science Foundation should significantly enhance funding for the development of integrated programs of training in population and the environment in U.S. universities.

3. Databases

Databases should be created that permit investigation of the effects of population and population change on consumption, human settlement, and land use from local to the global scale, and over time. Issues of data dissemination, quality control, and confidentiality should be addressed carefully.

4. Research

The National Science Foundation, the National Institutes of Health, and other agencies should provide targeted funding for research that significantly enhances efforts to understand the relationships between human populations and their environments. Of particular importance are the following issues:

- theoretical understanding of human demographic behavior including how people make decisions about childbearing, household formation, and residential location and how the environment affects these decisions
- theoretical and empirical understanding of how humans value the environment and how they adapt to a changing environment including degraded environments
- understanding of the environmental effects of urbanization in both urban and rural areas and how ecological footprints can be reduced
- understanding of the effects of population size and growth on the sustainability of resources (e.g., water, forests, soils, and food)
- understanding of rural to rural migration and to its relationships to the natural environment.

Environmental

public education

Environmental education is a multi-faceted tool that goes far beyond informing people about how to protect the environment. Such learning can help people make wise choices in all of their various roles—as consumers, employees, voters and citizens—by assimilating, analyzing and evaluating the complex and diverse sources of information, data and opinion about the environment. Such knowledge is essential if the United States and the world community are to meet the difficult challenge of achieving global sustainability for future generations. Yet, according to research sponsored by the National Environmental Education and Training Foundation (NEETF), American adults currently have only a "comic book-level" basis of environmental knowledge. This problem is further compounded by outdated—and sometimes inaccurate—information on the central causes of environmental degradation and the problems that result from it.

RECOMMENDATIONS

1. Environmental Education Prioritization
The Administration should make environmental education (EE) a top priority and encourage and fund EE partnership programs involving federal agencies, and state, tribal, local and private organizations.

2. Environmental Education Act
Congress should reauthorize the 1990 Environmental Education Act and increase the funding in this area by at least an order of magnitude.

3. Non-Traditional and Diverse Audiences
The Department of Education (DOED), National Science Foundation (NSF), Environmental Protection Agency (EPA), and other agencies should support research on the most effective methods to reach non-traditional and diverse audiences through EE.

4. Teacher Training
EPA, NSF, and DOED should encourage and support the availability of pre-service and in-service teacher training in EE for all teachers.

5. Non-Formal Education Programs
NSF, EPA and other federal agencies should increase support for EE curriculum development and dissemination through non-formal education programs such as 4-H, scouting, zoos, aquariums, nature centers, museums, etc.

6. Effectiveness of Environmental Education Programs
DOE, EPA, and NSF should support research to measure the effectiveness of EE programs, such as the Environment as an Integrating Context initiative.

7. Block Grants
DOED and EPA should provide block grants to states for EE programs.

8. Assessment
EPA, DOED, and NSF should cooperatively develop and implement a yearly assessment of public environmental knowledge (expanded from the existing NEETF/Roper Starch Survey).

9. Environmental Literacy
EPA, in cooperation with DOED, should assist states in integrating environmental literacy assessments in their on-going state assessments in order to develop baseline data on student environmental literacy.

10. North American Association of Environmental Education Guidelines
EPA, NSF, and DOED should promote the dissemination and use of the North American Association for Environmental Education (NAAEE) "Guidelines for Excellence" in EE to ensure that scientifically accurate and instructionally sound EE materials are used by educators.

sustainable communities

By integrating three basic elements—economic security, ecological integrity, and social equity—"community sustainability" becomes a concept that is simultaneously scientific, economic, social, political, psychological, ecological, ethical, and technical. These dimensions are interdependent and cannot be understood in isolation. Community sustainability requires both wise stewardship in environmental management and the ability to fulfill current basic human needs without compromising the ability of future generations to meet the needs they will have. Thus, government cannot "regulate" sustainability because it is not a project or program, but rather a process and a philosophy. Nonetheless, there is a major role for the federal government to play. It can serve communities by providing the scientific tools with which to measure sustainability and their progress towards sustainability, so that they are better able to assess their own status and make their own decisions

RECOMMENDATIONS

1. Sustainable Community Integrity
The National Science Foundation (NSF) and other federal agencies should fund research identifying and documenting the human elements that characterize sustainable communities.

2. Human-Nature Interactions
The NSF and other federal agencies should develop and fund science programs that undertake research from an "ecosystem approach" to identify the interactions of human settlements and natural systems.

3. Establishing Community Measures of Success
The NSF and other federal agencies should design scientific programs to collect data on projects that are intended to promote community sustainability and develop a systematic method for evaluating (measuring) these programs.

4. Information Delivery
The NSF, the Environmental Protection Agency and other federal agencies should develop programs and projects that will identify and implement mechanisms for translating scientific knowledge and enhancing information delivery, to assist decisionmakers and grassroots constituencies in identifying policies and practices that promote sustainability.

5. Institutional Structures to Address Sustainability
The Federal Government should support research to determine which institutional structures most effectively facilitate utilization of scientific information on sustainability in policy making at all levels of government.

Environmental

sustainable resource management

At the conclusion of the second millennium, society finds itself in an ironic situation in which most "renewable" natural resources (fisheries, forest products, grazing lands, agricultural genetic diversity, and other living resources) are in worse condition than many non-renewable natural resources such as minerals and inorganic materials. The problem is one facing many nations throughout the world, including the United States. This situation has resulted from a combination of many factors: a rapidly expanded and expanding human population; increased consumption and considerable waste of resources; a lack of information about ecological systems and their limits; failure to apply existing knowledge to environmental problems; historical attitudes about limitless resources; fragmented responsibilities and management; and a single-resource focus, to name only a few.

While scientific information is not the sole answer to achieving sustainability in resource management and resource consumption, science is essential if society is going to be able to: (1) secure a solid information base about how to manage resources sustainably; (2) find the means to communicate that information credibly and apart from political agendas; and (3) educate not only public and private decisionmakers, but also the general public.

GENERAL RECOMMENDATIONS

1. Science and Policymaking
Science should be an integral part of policymaking throughout the process, not only at the beginning.

2. Stakeholders
Local and regional stakeholders should be in involved in all decisionmaking about resource management.

3. Cross-boundary Conflicts
Mechanisms are needed to resolve conflicts that arise among stakeholders because of management units that cross political and jurisdictional boundaries.

4. Incentives
Incentives for public and private resource management that can supplement the regulatory environment should be established.

5. Public Understanding
Insufficient public understanding and acceptance of the scientific basis of resource management exacerbates already-existing tensions.

6. Analysis and Synthesis
The data that scientists currently provide for resource management often does not include the analysis and synthesis necessary for information to be usable in the policy sphere.

7. Legal Framework
The legal framework for connecting science with decisionmaking on natural resource issues should be reviewed and revitalized, taking into account the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ), and the Federal Advisory Committee Act (FACA), which often interferes with the flow of information among scientists, stakeholders, and federal decisionmakers.

SPECIFIC RECOMMENDATIONS

1. Education
The Department of Education, the Environmental Protection Agency (EPA), and the National Science Foundation (NSF) should support education and training, including curriculum development on sustainability for teachers of grades K-12.

2. Legal Guidance
The Department of Justice should develop guidance for judges to use in litigation involving resource management. Scientists should be involved in developing these guidelines.

3. Coordination
The Administration should examine jurisdictional conflicts in natural resource management and make recommendations for better coordination of the planning process across agency boundaries and across media including freshwater, marine, coastal, land, and air.

4. Scientific Uncertainty
Congress should fund a National Research Council (NRC) study to reexamine and develop an analytical framework for assessing the environmental impacts of various proposed management actions under the National Environmental Policy Act (NEPA) in the face of scientific uncertainty.

5. Council on Environmental Quality
The President and Congress should evaluate the role of the Council on Environmental Quality (CEQ) in overseeing the assessment of environmental impacts and the sustainability of management actions.

6. Research
The relevant Federal agencies (including NSF, EPA, DOE, USDA) should undertake comprehensive research efforts (including modeling) on complex environmental systems to better understand the interactions between human and natural systems with respect to long-term sustainability.

appendix 1

NATIONAL CONFERENCE ON SCIENCE, POLICY, AND THE ENVIRONMENT

December 7-8, 2000 | National Academy of Sciences | Washington, DC

Help shape the science for the environment agenda for the next Administration and Congress

THURSDAY, DECEMBER 7, 2000

1:00–1:15 **Welcome, Introductions, Conference Goal**
- Dr. Stephen Hubbell, University of Georgia, Chair, NCSE

1:15–2:00 **Keynote Address: Dr. Sylvia Earle, Deep Ocean Exploration and Research**

2:00–3:30 **Plenary I: A Science Agenda for the Next Century**
- Dr. Peter Saundry, NCSE
  Federal Spending on Environmental R&D (NCSE Report)
- Dr. Tom Graedel, Yale University
  Grand Challenges in Environmental Science (NAS Report)
- Dr. Virginia Dale, Oak Ridge National Laboratory
  Global Change Ecosystems Research (NAS Report)
- Dr. Robert Kates, Chair, NAS/NRC Coordinating Committee on a Transition to Sustainability
  Our Common Journey: A Transition Toward Sustainability (NAS Report) and Sustainability Science

4:00–5:15 **Plenary II: Environmental Science and Engineering for the 21st Century: The Role of the National Science Foundation.** Chaired by Dr. Tom Graedel, NSF Advisory Committee on Environmental Research and Education
- Dr. Jane Lubchenco, Chair, National Science Board Task Force on the Environment
- Dr. Margaret Leinen, Assistant Director for Geosciences and Environmental Coordinator, NSF
- Dr. Ann Kinzig, Arizona State University
  Workshop report on Nature and Society: An Imperative for Integrated Environmental Research

5:15–5:30 **Charge to Participants Prior to Breakout Sessions:** Looking through the prisms of different issues, suggest new approaches to improving the scientific basis for environmental decisionmaking.

5:30–7:00 **Buffet Reception**

7:00–8:30 **John H. Chafee Memorial Lecture on Science and the Environment** (NAS Auditorium)
- Introduction by Ambassador Richard E. Benedick, President, NCSE
- Remarks by Senator Lincoln Chafee (RI)
- Host Committee

THE CFC-OZONE PUZZLE: Environmental Science and Policy in the Global Arena
- Dr. F. Sherwood Rowland, Nobel Laureate, University of California, Irvine
- Dr. Mario J. Molina, Nobel Laureate, Massachusetts Institute of Technology

FRIDAY, DECEMBER 8, 2000

9:00–12:00 **Breakout Sessions:** Here's your opportunity to shape the "science for the environment" agenda of the next Administration and Congress. Each session is charged with generating a brief set of recommendations for improving the scientific basis for decision making within the topic area. These recommendations are not expected to be consensus views. Each session will open with short remarks from different stakeholding communities.

1:00–1:30 **Congressional Leadership Award: Rep. James Saxton (NJ)**

1:30–2:15 **Special Address: VISION ACROSS BOUNDARIES, Dr. Amory Lovins, Rocky Mountain Institute**

2:15–3:15 **Plenary III: Reports from Breakout Groups:** The proceedings and policy recommendations of participants will be developed into a Conference Report for submission to the new Administration and Congress.

3:30–5:00 **Closing Plenary: The New Administration and Congress:**
- Rep. Tom Udall (NM)
- F. Henry Habicht II, Global Environment & Technology Foundation
- David Goldston, Office of Rep. Sherwood Boehlert (NY)
- Ginny Worrest, Office of Senator Olympia Snowe (ME)

appendix 2

BREAKOUT SESSIONS

biodiversity & ecosystem health

SECTION A
Tom Bancroft, The Wilderness Society

Jim Manolis, Minnesota Department of Natural Resources

- Mike Soukup, National Park Service
- Jacob Stowers, Pinellas County, Florida

SECTION B
Ron Pulliam, University of Georgia

Curt Meine, Wisconsin Academy of Sciences

- K.C. Kim, Penn State University
- Gary Machlis, University of Idaho and National Park Service
- Ruth Reck, National Institute for Global Environmental Change

environmental implications of biotechnology

Lester Crawford, Georgetown University

Kathryn Papp, AAAS

environmental indicators

Judith Weis, Rutgers University

Keith Wendt, Minnesota Department of Natural Resources

- Susan Haseltine, U.S. Geological Survey
- Marvin Rosen, NJ Dept. of Environmental Protection
- Molly McMammon, Exxon Valdez Trustees Council

Note: **Session Chairs are designated in bold;**
Session Facilitators are designated in italic;
• Speakers are designated with bullets.

federal government structure

Terry Davies, Resources for the Future

Ellen Paul, American Institute of Biological Sciences

- Craig Peterson, former Majority Leader, State Senate of Utah
- Duncan Hardie, Environment Canada

global environmental change

SECTION A
Virginia Dale, Oak Ridge National Lab

Peter Folger, American Geophysical Union

- Peter Eisenberger, Columbia University
- Stan Greenfield, National Council for Science and the Environment

SECTION B
Robert Worrest, CIESIN, Columbia University

Chris Calamita, University of Louisville

- Priscilla Grew, University of Nebraska
- Jonathan Patz, Johns Hopkins University
- Felicia Davis Gillmore, Georgia Airkeepers

higher education

Rick Clugston, University Leaders for a Sustainable Future

John Glyphis, Second Nature

Cornelia Burr, Attorney & Consultant

- Walter Leal Filho, TuTech, Hamburg, Germany
- Bruce Coull, University of South Carolina

human health and the environment

Howard Frumkin, Emory University, Rollins School of Public Health

Howard Frumkin, Emory University, Rollins School of Public Health

- Lynn R. Goldman, Johns Hopkins School of Health
- Samuel H. Wilson, National Institute of Environmental Health Sciences
- Members of Roundtable on Environment Health Sciences Research and Medicine at the Institute of Medicine

information systems

Mark Schaefer, Association For Biodiversity Information

Fred Stoss, SUNY-Buffalo & Special Library Association

Kevin Hutton, National Council for Science & Environment

invasive species

Jamie Reaser, National Invasive Species Council

Gordon Brown, National Invasive Species Council

- Phyllis Windle, Union of Concerned Scientists

pollution prevention/waste management

Robert Anex, University of Oklahoma

Clint Andrews, Rutgers University

Michele Blazek, AT&T

Jill Engel-Cox, Battelle Memorial Institute

- Emily Matthews, World Resources Institute
- Alicia Culver, INFORM, Inc.
- Karl Schmidt, Johnson & Johnson

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Elaine Hoagland, Council on Undergraduate Research

- Vern Cardwell, University of Minnesota
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- Eric Holst, Doris Duke Charitable Trust
- Joe Norbeck, University of California Riverside

appendix 3

ACRONYMS & ABBREVIATIONS:

CENR: Committee on Environment & Natural Resources

CEQ: Council on Environmental Quality

DOC: Department of Commerce

DOD: Department of Defense

DOE: Department of Energy

DOED: Department of Education

DOI: Department of the Interior

DOJ: Department of Justice

ENR: Energy and Natural Resources

EPA: Environmental Protection Agency

FACA: Federal Advisory Committee Act

GISP: Global Invasive Species Project

NAS: National Academy of Sciences

NAAEE: North American Association for Environmental Education

NCSE: National Council for Science and the Environment

NEETF: National Environmental Education and Training Foundation

NEII: National Environmental Information Infrastructure

NEPA: National Environmental Policy Act

NISC: National Invasive Species Council

NIEHS: National Institute of Environmental Health Sciences

NIH: National Institutes of Health

NIST: National Institute of Standards & Technology

NRC: National Research Council

NSF: National Science Foundation

NSTC: National Science and Technology Council

OTA: Office of Technology Assessment

OSTP: Office of Science & Technology Policy

PHS: Public Health Service

UNEP: United Nations Environmental Programme

USAID: United States Agency for International Development

USDA: United States Department of Agriculture

USGCRP: United States Global Change Research Program

WHO: World Health Organization

appendix 4

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appendix 5

SUSTAINABILITY SCIENCE

statement of the friibergh workshop on sustainability science

Friibergh, Sweden, 11-14 October 2000

The world's present development path is not sustainable. Efforts to meet the needs of a growing population in a globalizing, unequal and human-dominated world will continue to exert unsustainable pressures on the Earth's essential life-support systems. Worrying interactions among climate change, loss of biological diversity, increasing poverty and disease, and growing inequality combine to increase the vulnerability of humans and nature. Meeting fundamental human needs while preserving the life-support systems of Earth will require a worldwide acceleration of today's halting progress in a transition toward sustainability. A response as to how this transition might be achieved has begun to emerge in recent reports of national and international scientific organizations, as well as from independent networks of activists and scientists.

To take these ideas further, two dozen scientists, drawn from the natural and social sciences and from across the world, convened at Sweden's Friibergh Manor in October 2000. Participants concluded that promoting the goal of sustainability requires the emergence and conduct of the new field of sustainability science.

Sustainability science seeks to improve on the substantial but still limited understanding of nature-society interactions gained in recent decades. This has been achieved through work in the environmental sciences estimating and evaluating human impacts, and evidence from social and development studies that takes into account environmental influences on human well-being. What is urgently needed now is a better general understanding of the complex dynamic interactions between society and nature so that the alarming trend towards increasing vulnerability is reversed.

This will require major advances in our ability to analyze and predict the behavior of complex self-organizing systems, characterize the irreversible impacts of interacting stresses, interpret multiple scales of organization, and assess the roles of various social actors with divergent expectations. Much contemporary experience points to the need to address these issues through integrated scientific efforts focused on the social and ecological characteristics of particular places or regions. The workshop formulated an initial set of core questions that examines the combinational character of nature-society interactions, our ability to guide those interactions along more sustainable trajectories, and ways to promote and implement the social learning that will be essential to the navigation of a transition to sustainability.

By structure, method, and content, sustainability science must differ fundamentally from most science, as we know it. Familiar approaches to developing and testing hypotheses are inadequate because of non-linearity, complexity, and long time lags between actions and their consequences. Additional complications arise from the recognition that humans cannot stand outside the nature-society system. The common sequential analytical phases of scientific inquiry such as conceptualizing the problem, collecting data, developing theories and applying the results will become parallel functions of social learning, which incorporate the elements of action, adaptive management and policy as experiment.

Sustainability science will therefore need to employ new methodologies that generate the semi-quantitative models of qualitative data, build upon lessons from case studies, and extract inverse approaches that work backwards from undesirable consequences to identify pathways that can avoid such outcomes. Scientists and practitioners will need to work together with the public at large to produce trustworthy knowledge and judgment that is scientifically sound and rooted in social understanding.

Furthermore sustainability science will learn to work with all manner of social groups to recognize how they come to gain knowledge, establish certainty of outlooks, and adjust their perceptions as they relate to each other's needs. This in turn will require sustainability science to sense better how governments are responding, how democracies are improving and how citizens generally act to play out the sustainability transition.

Meeting the challenge of sustainability science will also require new styles of institutional organization to foster and support inter-disciplinary research over the long term; to build capacity for such research, especially in developing countries; and to integrate such research in coherent systems of research planning, assessment and decision support. We need to be able to involve scientists, practitioners, and citizens in setting priorities, creating new knowledge, evaluating its possible consequences, and testing it in action. This will require integration of this new active knowledge in particular locations and cultural settings through broader networks of research and monitoring.

In the coming years, the emerging field of sustainability science will need to move forward along several pathways if it is to prove successful. There will be wide discussion within scientific communities, North and South, of the approach, its key questions, methods of inquiry, and institutional needs. There should be an effort to reconnect science to the many political efforts for promoting sustainable development. One benchmark is the forthcoming "Rio + 10" Conference that will review developments in science over the decade since the UN Conference on Environment and Development. And across the continents, in groups small and large, research relating to sustainability science is under way and accelerating. This research can be connected and enhanced, and it can transform itself into the core of an effective new field

Note: Participants at the Workshop were B. Bolin, W. Clark, R. Corell, N. Dickson, S. Faucheux, G. Gallopin, A. Gruebler, M. Hall, B. Huntley, J. Jager, C. Jaeger, N. Jodha, R. Kasperson, R. Kates, I. Lowe, A. Mabogunje, P. Matson, J. McCarthy, H. Mooney, B. Moore, T. O'Riordan, J. Schellnhuber, and U. Svedin. A report on the Workshop, together with updates on a larger follow up meeting to be held a year hence in the Southern Hemisphere, will be posted on **http://sustainabilityscience.org**.

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TOPICAL RECOMMENDATIONS

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IMPLEMENTING ORGANIZATIONS

Note: The citations below indicate specific recommendations that were proposed to be carried out by a particular agency or department. Many recommendations refer to "the federal government" or a multi-agency program, etc.