Participant Manual

Ecological Risk and Decision Making Workshop

U.S. Environmental Protection Agency
Office of Policy, Planning and Evaluation
Office of Sustainable Ecosystems and Communities
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ACKNOWLEDGMENTS

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TABLE OF CONTENTS

Ecological Risk and Decision Making Workshop

Schedule

Day 1

8:30 - 8:45	Introductions & Logistics
8:45 - 9:30	Introduction Unit
9:30 - 10:30	Ecology and Ecological Effects Unit
10:30 - 10:45	*BREAK*
10:45 - 12:00	Ecology and Ecological Effects Unit
12:00 - 1:00	*LUNCH*
1:00 - 2:00	Ecological Risk Management and Decision Making Unit
2:00 - 2:45	Ecological Risk Assessment Unit
2:45 - 3:00	BREAK
3:00 - 4:00	Communicating with the Public on Ecological Issues
4:00 - 5:00	Guest Speaker, Video, Field Trip, or What-If Bug Exercise

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Day 2

8:30 - 9:30	Ecological Risk Assessment Framework Overview Unit
9:30 - 10:30	Group Exercise (choices include: Superfund Site or Pesticide Review) - Problem Formulation Phase
10:30 - 10:45	*BREAK*
10:45 - 12:00	Group Exercise - Problem Formulation Phase
12:00 - 1:00	*LUNCH*
1:00 - 3:00	Group Exercise - Analysis Phase
3:00 - 3:15	*BREAK*
3:15 - 5:00	Group Exercise - Risk Characterization Phase

Day 3

8:30 - 10:30	Group Exercise - Decision Making
10:30 - 10:45	*BREAK*
10:45 - 11:15	Group Exercise - Final Report-Out
11:15 - 12:00	Workshop Summary & Evaluation

Ecological Risk and Decision Making Workshop
Participant Evaluation Form
1. Introduction

Name (optional): ____________________

Office: ____________________

Title: ____________________

Please mark the appropriate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

Ecological Risk and Decision Making Workshop
Participant Evaluation Form
2. Ecology and Ecological Effects

Name (optional): ______________________________

Office: ______________________________

Title: ______________________________

Please mark the appropnate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comment [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

Ecological Risk and Decision Making Workshop
Participant Evaluation Form
3. Risk Management and Decision Making

Name (optional): ______________________________

Office: ______________________________

Title: ______________________________

Please mark the appropriate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

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Ecological Risk and Decision Making Workshop
Participant Evaluation Form
4. Ecological Risk Assessment

Name (optional): ______________________________

Office: ______________________________

Title: ______________________________

Please mark the appropnate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

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Ecological Risk and Decision Making Workshop
Participant Evaluation Form
5. Communicating with the Public on Ecological Issues

Name (optional): ______________________________

Office: ______________________________

Title: ______________________________

Please mark the appropriate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

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Ecological Risk and Decision Making Workshop
Participant Evaluation Form
6. Framework for Ecological Risk Assessment

Name (optional): ____________________

Office: ____________________

Title: ____________________

Please mark the appropriate box.

Overall

How would you rate the this unit? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments [Please comment on such aspects as the manual; visual aids; instructor's presentation; pacing; amount of detail (too much, too little, just right); usefulness]

Ecological Risk and Decision Making Workshop
Participant Evaluation Form
Overall Course

Name (optional): ____________________

Office: ____________________

Title: ____________________

Please mark the appropriate box.

Overall

How would you rate the overall workshop? ☐ Excellent ☐ Good ☐ Fair ☐ Poor

Workshop Sessions

How would you rate the six main units?

Introduction	☐ Excellent ☐ Good ☐ Fair ☐ Poor
Ecology and Ecological Effects	☐ Excellent ☐ Good ☐ Fair ☐ Poor
Risk Management and Decision Making	☐ Excellent ☐ Good ☐ Fair ☐ Poor
Ecological Risk Assessment	☐ Excellent ☐ Good ☐ Fair ☐ Poor
Communicating with the Public on Ecological Issues	☐ Excellent ☐ Good ☐ Fair ☐ Poor
Framework for Ecological Risk Assessment	☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments ____________________

Group Exercises

In which group exercise did you participate? ____________________

Did the group exercise reinforce what you learned in the six main units? What is your opinion of the group exercise in which you participated? (How informative/educational was it?) Use the space below for comments.

☐ Excellent ☐ Good ☐ Fair ☐ Poor

Comments ____________________

Please rate the following:

Visual Aids	☐ Excellent	☐ Good	☐ Fair	☐ Poor
Workshop Manual	☐ Excellent	☐ Good	☐ Fair	☐ Poor

Which aspects of the workshop were most beneficial and why? ______________________

Were any parts of the course or course materials confusing or difficult to understand? ______________

After participating in this workshop, do you feel you have a better understanding of ecology and the ecological risk assessment and the decision making process? ☐ Yes ☐ No

Do you have any suggestions on how information could be presented more effectively?

Are there aspects of the workshop that you think need more/less emphasis?

Did the workshop meet your expectations? ☐ Yes ☐ No

Please provide any other comments or suggestions in the space below.

Thank you for your assistance!

1. Introduction

1. INTRODUCTION UNIT

Contents

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Summary of Introduction Unit

Time Allotted

Approximately 45 minutes allowed for discussion and lecture.

Summary of the Unit

The Introduction Unit establishes the purpose of the course. It defines ecological risk assessment, and places ecological risk in the context of human health risk and the ecosystem protection place-based approach. The bases for ecological protection and risk assessment at EPA are also reviewed.

Key Concepts

- People hold a wide range of values concerning ecological protection.
- Ecological protection and risk are firmly based in the EPA's statutes and mission.
- Ecological risk assessment is "a process that evaluates the likelihood that adverse effects may occur or are occurring as a result of exposure to one or more stressors."
- Ecological risk is increasingly a consideration in decision making at EPA.
- Ecological risk assessment is a methodology that can be used to develop strategies for protecting ecosystems.

References

USEPA. 1992. *Framework for Ecological Risk Assessment.* EPA/630/R-92/001. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

USEPA Science Advisory Board. 1990. *Reducing Risk: Setting Priorities and Strategies for Environmental Protection.* SAB-EC-90-021. U.S. Environmental Protection Agency, Washington, DC.

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Purpose of Workshop

- **To provide a fundamental understanding of terms, concepts, and issues associated with ecology, ecological risk assessment, communicating about ecological issues to the public, and risk-based decision making.**
- **To raise the level of awareness, interest and knowledge about ecological protection.**
- **To improve the use of ecological risk assessment in the decision making process.**

This workshop was developed to provide a basic understanding of the terms, concepts, and issues associated with ecology, ecological risk assessment, communicating about ecological issues to the public, and risk-based decision making at EPA.

It is based on the *Framework for Ecological Risk Assessment* developed by EPA's Risk Assessment Forum. The 1983 National Academy of Sciences (NAS) risk assessment paradigm was used as the foundation for the *Framework*. However, significant modifications to the NAS paradigm were made to adapt it to ecological situations.

It is also provided to fill EPA's need for increased information to help address ecological issues in the analyses and decisions made by the agency.

The goal is to raise the level of awareness about ecological protection and improve the use of ecological risk assessment in the decision making process at EPA.

OVERVIEW OF INTRODUCTION UNIT

This introduction to the course will:

- Examine the wide range of views people hold with regard to ecological protection;
- Provide an overview of the statutory and regulatory basis for ecological protection at EPA;
- Define ecological risk assessment;
- Discuss the basis for an ecological risk assessment approach; and
- Show the relationship of ecological risk assessment to community-based environmental protection.

Why Are We Concerned About Ecological Protection?

We are concerned about ecological protection because it is firmly established in our environmental laws. Consideration of ecological protection issues in environmental decision making is necessary to maintain the health of our natural world for the use and enjoyment and sustainability of future generations. EPA is the primary Federal agency responsible for implementing the nation's environmental laws. As different environmental problems have been identified over the years, new environmental laws were passed to address each new problem. EPA's internal programmatic structure mirrors the environmental legislation that it is required to implement. The ecological protection language in the major environmental laws for which EPA is responsible is summarized below.

National Environmental Policy Act (NEPA) of 1969

NEPA recast the government's role; formerly the conservator of wilderness, with NEPA it became the protector of earth, land, air, and water. Its passage paved the way for the establishment of the EPA.

"The purposes of NEPA are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation..."[1]

NEPA requires Federal agencies to evaluate the environmental impacts associated with major actions that are federally funded, supported, permitted, licensed, or implemented. Federal agencies are required to prepare an environmental impact statement (EIS) for any Federal action which significantly affects the environment.

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[1] Quotations for NEPA, CWA, and RCRA were taken from *Selected Environmental Law Statutes*, West Publishing Co., St. Paul, MN, 1984.

Why Are We Concerned About Ecological Protection? (Continued)

National Environmental Policy Act (NEPA) of 1969 (Continued)

EPA's primary role in NEPA involves reviewing EISs. EPA reviews determine whether or not the EIS adequately and completely considers the environmental aspects of the proposed action including reasonable alternatives and comments on the environmental acceptability of the proposed project.

Clean Water Act (CWA)

The objective of the CWA...:

- "is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."
- "it is the national goal that whenever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife..."
- "it is the national policy that the discharges of toxic pollutants in toxic amounts be prohibited..."

Section 316 (a) of the Act states: "...the administrator may impose an effluent limitation...with respect to the thermal component of such discharge...that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water."

Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972

The MPRSA allows EPA to permit ocean dumping where it "determines that such dumping will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[2] Further, before issuing a permit, EPA must consider such effects of discharges as "potential changes in marine ecosystem diversity, productivity, and stability, and species and community population dynamics."[3]

Endangered Species Act (ESA)

EPA is required to comply with the Endangered Species Act by consulting with the Department of Interior or Commerce (for marine species) on any action which is authorized, funded, or carried out by the Agency which may jeopardize the continued existence of any endangered or threatened species, or result in the destruction or adverse modification of critical habitats. (The Appendix of this Manual has policy papers on endangered species.)

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[2] 33 U.S.C. Sec. 1412.

[3] 34 U.S.C. Sec. 1412.

Why Are We Concerned About Ecological Protection? (Continued)

Endangered Species Act (Continued)

Section 2(c) also states: "Federal departments and agencies shall seek to conserve endangered and threatened species, and shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species."

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Several sections of CERCLA, commonly known as Superfund, make reference to protection of health and the environment as parts of a whole.

- Section 105(a)(2) calls for methods to evaluate and remedy "any releases or threats of releases...which pose substantial danger to the public health or to the environment."
- Section 121(b)(1) requires selection of remedial actions that are "protective of human health and the environment."
- Section 121(c) calls for "assurance that human health and the environment continue to be protected."
- Section 121(d) directs EPA to attain a degree of cleanup "which assures protection of human health and the environment." (CERCLA information from EPA's *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual*, EPA/540/1-89/001, 1989.)

Environment is defined in CERCLA as "the navigable waters, the waters of the contiguous zone, and the ocean waters of which the natural resources are under the exclusive management authority of the United States under the Magnuson Fishery Conservation and Management Act; and any other surface water, ground water, drinking water supply, land surface or subsurface strata, or ambient air within the United States or under the jurisdiction of the United States."

The National Contingency Plan (NCP) allows for the "efficient, coordinated, and effective response to discharges of oil and releases of hazardous substances, pollutants, and contaminants in accordance with the authorities of CERCLA and the CWA."[4] As part of the NCP, the Agency must identify at least 400 of the highest priority hazardous waste facilities in the U.S. needing investigation or remedial attention.[5] The statute requires the NCP to develop criteria that take into account "the potential for destruction of sensitive ecosystems..."[6] A revised Hazard Ranking System rule (1990), which includes more ecological factors and

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[4] 40 CFR 300.3(a)(1)(b) (1985 NCP).

[5] 42 U.S.C. Sec. 9605(a)(8)(B).

[6] 42 U.S.C. Sec. 9605.

Why Are We Concerned About Ecological Protection? (Continued)

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Continued)

sensitive environments, can now result in sites being placed on the National Priority List solely because of ecological risks. Remedial action decisions must comply with applicable or relevant and appropriate regulations (ARAs), such as the Endangered Species Act, CWA, and Migratory Bird Treaty Act.

CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 establishes liability for damages to natural resources resulting from the release of hazardous materials.[7] Only the Natural Resource trustees, e.g., the Department of Interior and the National Oceanic and Atmospheric Administration, may sue to recover damages to natural resources. The EPA is not a trustee; however, it does play a critical role in promoting natural resource damage assessments by gathering information on damages, notifying trustees, and assigning duties to trustees.

Resource Conservation and Recovery Act (RCRA)

"The objectives of RCRA are to promote the protection of health and the environment...by prohibiting future open dumping on the land and requiring the conversion of existing open dumps to facilities which do not pose a danger to the environment or to health; regulating the treatment, storage, transportation, and disposal of hazardous wastes which have adverse effects on health and the environment..."

The 1984 Hazardous and Solid Waste Amendments significantly expanded the scope and requirements of RCRA to include the consideration of ecological impacts and incorporate ecological endpoints. The statute required EPA to consider ecological impacts in Reports to Congress and in the Regulatory Determinations for special wastes (e.g., high-volume, low-toxicity wastes).

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

FIFRA requires that before a product can be registered unconditionally, it must be shown that it can be used without "unreasonable adverse effect on the environment" [FIFRA section 3(c)(6)]; that is, without causing "any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs, and benefits of the use of the pesticide" [FIFRA section 2(bb)]. FIFRA defines the environment to include "water, air, land, and all plants and man and other animals living therein, and the interrelationships which exist among these."[8]

7 42 U.S.C. Sec 9607(f).

8 7 U.S.C. Sec. 136(J).

Why Are We Concerned About Ecological Protection? (Continued)

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (Continued)

EPA can initiate a special review of a pesticide if the Administrator determines, "based on a validated test or other significant evidence," that the use of the pesticide may:

- "result in residues in the environment in nontarget organisms at levels which equal or exceed concentrations acutely or chronically toxic to such organisms, or at levels which produce adverse reproductive effects in such organisms, as determined from tests conducted on representative species or from other appropriate data;" or

- pose a risk to the environment that is "of sufficient magnitude to merit a determination whether the use of the pesticide product offers offsetting social, economic, and environmental benefits that justify initial or continued registration."

Other criteria for initiating special review include considerations regarding endangered species and habitat destruction. (Criteria for Initiation of Special Review, 40 CFR 1154.7, 1990.)

Toxic Substances Control Act (TSCA)

TSCA mandates that "adequate data be developed with respect to the effect of chemical substances and mixtures on health and the environment," and gives EPA the authority to regulate "chemical substances and mixtures which present an unreasonable risk of injury to health or the environment" [TSCA section 2(b)(1) and (2)]. The statute defines environment to include "water, air, and land and the interrelationship which exists among and between water, air, and land and all living things."[9]

TSCA requires the producer of a new chemical to submit a premanufacturing notification (PMN), including "all existing data concerning the environmental and health effects of such substance or mixture" [TSCA Section 8(a)(2)(E)].

Section 4 of TSCA requires that testing be conducted for existing chemicals that:

- May present an unreasonable risk of injury to health or the environment; and

- Require testing to provide sufficient data to determine whether unreasonable risk exists [TSCA Section 4(a)(1)(A)].

[9] 15 U.S.C. Sec. 2602(5).

Why Are We Concerned About Ecological Protection? (Continued)

Clean Air Act (CAA)

The CAA requires EPA to:

- "Protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare" [CAA Section 101(b)(1)];

- Regulate hazardous air pollutants that present "adverse environmental effects" (CAA Section 112); and

- "Preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreation, scenic, or historic value" [CAA Section 160(2)] and "prevent significant deterioration of air quality in each " [CAA Section 302(h)].

Secondary National Ambient Air Quality Standards must be adequate to protect public welfare from any known or anticipated adverse effects associated with the presence of a listed ambient air pollutant. Public welfare is defined in CAA Section 302(h) as "...includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate..."

Section 401(a)(1) of Title IV of the CAA states: "The presence of acidic compounds and their precursors in the atmosphere and in deposition from the atmosphere represents a threat to natural resources, ecosystems materials, visibility and public health." Section 404 requires that the Administrator report to Congress on the feasibility and effectiveness of an acid deposition standard or standards to protect sensitive and critically sensitive aquatic and terrestrial resources.

Global warming is addressed in the Clean Air Act Amendments of 1990, stating "To the maximum extent practicable, Class I and Class II [ozone-depleting] substances shall be replaced by chemicals, product substitutes, or alternative manufacturing processes that reduce overall risks to human health and the environment."

ECOLOGICAL RISK ASSESSMENT - A Tool for Ecological Protection

Definition:

"A process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more *stressors*."

Framework for Ecological Risk Assessment
USEPA Risk Assessment Forum

Ecological risk assessment is a tool for ecological protection. There are a number of ways of doing an ecological risk assessment (see Ecological Risk Assessment Unit). This workshop uses the definition of ecological risk assessment developed by EPA's Risk Assessment Forum (RAF), a standing committee of EPA scientists charged with developing Agency-wide risk assessment guidelines. The *Framework for Ecological Risk Assessment* was the initial product of the RAF's efforts. (The *Framework* is included in the Appendix of this Manual.)

Ecological means pertaining to ecology, or the natural environment, which includes physical features and all the plants and animals in an area.

Risk assessment refers to an appraisal or estimate of the likelihood of adverse effects.

A **stressor** is any physical, chemical, or biological entity that can induce an adverse effect.

Stressors can take many forms. Some examples are:

- **Chemical**: Acidic precipitation decreasing the pH of streams and ponds, making them less suitable, or even unsuitable, for aquatic life.

- **Physical**: Highway construction activities that remove or alter habitat.

- **Biological**: The introduction of a non-native (exotic) plant which, lacking natural checks and balances, competes against and replaces native species.

More information on stressors will be presented in the Framework Unit.

Why An Ecological Risk Assessment Approach?

- **Statutory requirements**
- **EPA Science Advisory Board Report**
- **Tool to set priorities**
- **Tool to communicate clearly to the public**

Environmental Statutes and Ecological Risk Assessment

Clearly, ecological protection is an important component of the major environmental statutes administered by EPA. However, those statutes do not describe how to assess adverse ecological effects. All the statutes allow, and some appear to encourage ecological risk assessments. Some statutes have specific ecological risk language:

CWA, Section 301(g)(2)(c): To obtain a modification (to effluent limitations for certain nonconventional pollutants), there must be no interference with the attainment or maintenance of water quality which assures protection and propagation of a balanced population of shellfish, fish, and wildlife: the modification must not pose an **unacceptable risk to the environment** because of bioaccumulation, persistency in the environment, acute toxicity, chronic toxicity, or synergistic propensities.

CERCLA 105(a)(8)(A): The statute states that criteria to determine priorities among releases are to be based upon **relative risk** or danger to public health or welfare or **the environment**, considering the potential for destruction of sensitive ecosystems, the damage to natural resources which may affect the human food chain, the contamination or potential contamination of the ambient air, and other factors.

The National Contingency Plan states that, "Using the data developed under paragraphs (d)(1) and (2) of this section [remedial investigation], the lead agency shall conduct a site-specific **baseline risk assessment** to characterize the current and potential threats to human health and the **environment**... The results of the baseline risk assessment will help establish acceptable exposure levels for use in developing remedial alternatives in the FS [feasibility study]..."

Why An Ecological Risk Assessment Approach? (Continued)

Environmental Statutes and Ecological Risk Assessment (Continued)

FIFRA Section 2 (bb) & 3 (c)(6): Before a product can be registered unconditionally, it must be shown that it can be used without "unreasonable adverse effect on the environment..." That is, without causing "any **unreasonable risk to** man or **the environment**, taking into account the economic, social and environmental costs, and benefits of the use of the pesticide."

TSCA Section 2 (b)(1) and (2): TSCA mandates and gives EPA the authority to regulate "chemical substances and mixtures which present an **unreasonable risk of injury to** health or **the environment.**"

CAA Amendments of 1990: "To the maximum extent practicable, class I and class II [ozone-depleting] substances shall be replaced by chemicals, product substitutes, or alternative manufacturing processes that **reduce overall risks** to human health and **the environment.**"

Science Advisory Board Report

The Science Advisory Board (SAB) of EPA issued a report, entitled ***Reducing Risk: Setting Priorities And Strategies for Environmental Protection (1990)***, which recommended that "EPA should attach as much importance to reducing ecological risk as it does to reducing human health risk."

The SAB recognized the very close linkages between human health and ecological health. It recognized that natural resources have an intrinsic moral value that must be measured on its own terms and protected for its own sake.

The report also stated "...the Agency should communicate to the general public a clear message that it considers ecological risks to be just as serious as human health and welfare risks..."

Tools to Set Priorities

Ecological risk assessments can be used to set priorities. For example, in a watershed risk assessment, problems impairing the watershed are identified and assessed, and management actions such as mitigation, research, monitoring, and regulatory actions are prioritized. This entire process involves stakeholders and risk managers.

Tools to Communicate Clearly with the Public

Risk assessment can be used as a public communication tool to describe, in plain language, the resources being threatened. This allows the public and decision makers an opportunity to understand and discuss the issues.

Ecological Risk Assessment
and
Community - Based
Environmental Protection

EPA's Community-Based Environmental Protection Approach

Community-based environmental protection (CBEP) is a place-based approach, developed under the direction of EPA Administrator Carol Browner, and is one of the new ecological initiatives in the Agency. In the past, EPA has concentrated on issuing permits, establishing pollutant limits, and setting national standards. We are now recognizing that even perfect compliance with all of EPA's authorities would not ensure the reversal of disturbing environmental trends such as the decline of the salmon population in the Pacific Northwest and the oyster stock in the Chesapeake Bay, the decline in migratory bird populations, and degraded coral reef systems. In short, until recently EPA has been program-driven rather than ecosystem- or "place-" driven. This new "place-based approach" advocates a change from individual programs to building on and integrating these programs to provide a more holistic treatment of key environmental problems. Ecosystem protection will rely on stakeholders to define problems, set priorities, and to help with solutions. It will include protection of human health and welfare, as well as protection of natural systems within the context of EPA's statutory mandates. It is important to note, however, that the ecosystem protection approach came from the scientific community; EPA did not originate this approach.

The Edgewater Consensus

On March 5, 1994, EPA convened a meeting which resulted in the Edgewater Consensus. This agreement took its name from the Smithsonian Environmental Research Center in Edgewater, MD, where the meeting was conducted. The attendees consisted of senior EPA leaders from both Headquarters and the Regions, to discuss how EPA could respond to the growing mandate to address human health and ecological concerns within an economic, social and geographic context.

EPA's Community-Based Environmental Protection Approach (Continued)

The Edgewater Consensus (Continued)

The result was a call for a fundamental reorientation of EPA to strategically address priorities in different places. This included the idea that ecosystem protection is place-based environmental management, driven by the environmental problems in each ecosystem. EPA would establish a process to determine site-specific environmental problems and integrate the solutions with the goal of long-term ecosystem health and stability. This process would include:

- Establishing a process for identifying places and steps to implement ecosystem protection in each place based on local considerations;
- Coordinating both within the Agency and with states, tribes, local governments, and key stakeholders; and
- Identifying tools that could be provided at a national level in support of these local efforts.

CBEP Project Example: Lake Champlain Basin Program

The Lake Champlain watershed includes portions of Vermont, northeastern New York and the Province of Quebec, Canada. The Lake is 110 miles long and 12 miles wide at its widest. The total area of the watershed is 8,200 square miles. The major environmental problems in the watershed include nutrient enrichment, particularly phosphorus from point and non-point sources, toxic substances in localized areas, mercury and PCB contaminated fish, non-native nuisance aquatic vegetation and fauna (e.g., zebra mussels), and habitat loss.

The Lake Champlain Management Conference (LCMC) was established to develop pollution prevention and control and a restoration plan for Lake Champlain and its watershed. The LCMC is comprised of 31 representatives from Vermont and New York including Federal, state and local governments; local interest groups; citizens; academics; business representatives; legislators; farmers; and environmental groups. The LCMC has collaboratively developed goals for each of 11 action areas and jointly decided on activities the program will undertake to address these goals. Funding has been used for research, education and demonstrations of aspects of ecosystem management, including a study of food web dynamics and lake hydrodynamics, developing wetland acquisition strategies, and undertaking fish consumption surveys. The business representatives on the LCMC and local business community are interested in developing a plan which works with and supports the local economy (mostly tourism). The LCMC had undertaken economic impact studies and local community case studies to understand the relationship of the plan to the economy.

Role of Ecological Risk Assessment

Ecological risk assessment is a methodology that can be used to develop strategies for protecting ecosystems. With stakeholder participation, it involves developing management goals for an ecosystem based on the condition of the ecosystem, societal values, and a number of possible stressors to the ecosystem. Management goals may include achieving acceptable ecosystem functions or preserving and protecting the ecosystem from future stressors.

The analysis examines the response (current and future) of the ecosystem to multiple stressors. The results of the risk assessment lead to proposed management actions (e.g., mitigation, research and monitoring). The entire process is iterative, i.e., as more information is obtained, the risk assessment can be refined.

Key Concepts

- **People hold a wide range of values concerning ecological protection.**
- **Ecological protection and risk are firmly based in EPA's statutes and mission.**
- **Ecological risk assessment is "a process that evaluates the likelihood that adverse effects may occur or are occurring as a result of exposure to one or more stressors."**

Key Concepts (Continued)

- **Ecological risk is increasingly a consideration in decision making in EPA programs.**
- **Ecological risk assessment is a methodology that can be used to develop strategies for protecting ecosystems.**

2. Ecology and Ecological Effects

2. ECOLOGY AND ECOLOGICAL EFFECTS UNIT

Contents

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Summary of Ecology Unit:

Time Allotted

Approximately 2 hours are allowed for discussion and lecture.

Summary of the Unit

This unit presents a general overview of ecology to provide participants with the basic concepts and terminology underlying ecological risk assessments. The information includes a discussion of the types of stressors and related ecological effects.

Key Concepts

- Ecosystems are complex and dynamic, composed of interacting networks of **biotic** and **abiotic** components.
- Principal **ecological components** are individuals, populations, communities, and ecosystems.
- Critical to the function of an ecosystem is the flow of energy and nutrients through the system's producers and consumers.
- **Stressors** can affect individual organisms, population growth, community structure and function, and ecosystem processes.
- Interactions among individuals in a population, and among populations in a community influence the **significance** of a stressor's ecological effects.
- The combination of stressor, environmental, and biological characteristics dictates the nature, extent, and magnitude of ecological effects.

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**ECOLOGY AND
ECOLOGICAL EFFECTS
UNIT**

ECOLOGY AND ECOLOGICAL EFFECTS

- **Basic Concepts in Ecology**
- **Ecological Effects of Stressors**

There are certain concepts that are important to understand to improve appreciation of ecological risk assessments. This unit will provide a brief review of ecological concepts, and the ecological effects of man-made activities and natural stressors.

Basic Concepts in Ecology

Ecology — *oikos* ("house") *logos* ("governing rules")

Focus — the primary levels of ecological organization: species, populations, communities, and ecosystems.

Basic Concepts in Ecology

The term "ecology" comes from the Greek phrase *oikos* ("house") *logos* ("governing rules"), literally "the rules of the house." The "rules" refer to the array of relationships and interconnections through which organisms interact with their environments.

Organisms do not live in isolation but occur in systems that exhibit a certain structure and function, such that the behavior of the whole is greater than the sum of the parts and therefore, very difficult to predict.

- Just as the cell and the entire individual organism represent levels of a system, so do populations of individuals of the same species and communities of populations characterizing ecosystems (Howell, 1994).
- Ecology is the study of systems in which there are interactions among living organisms, and between those organisms and the landscapes they inhabit. These relationships and interactions can generally be characterized in the following manner:
  - Among individuals within a population;
    - Social interactions among members of a wolf pack, or breeding behavior among stoneflies in a mountain stream.
  - Between individuals of different populations;
    - Predator-prey interactions between wolves and moose, or the importance of spottail shiners in the diet of green herons.

Basic Concepts in Ecology (Continued)

- Between organisms and their physical surroundings;
    - The relationship between gopher holes and soil microorganisms, or the influence of river water levels and muskrat populations.

This unit focuses on four primary levels of ecological systems:

- Species;
- Population;
- Community; and
- Ecosystem.

In doing so, the materials introduce and define some of the ideas and terms commonly used in ecology.

SPECIES

A group of actually or potentially interbreeding organisms that are reproductively isolated from other organisms.

Two animals of the same species will not necessarily look exactly alike. Widely distributed species often have different physical or behavioral characteristics. As a familiar example, consider the species *homo sapiens*. Humans exhibit considerable variety in skin, hair and eye color, size, etc. This same type of variety also occurs in plant and animal species.

POPULATIONS

Populations are groups of organisms of the same species occupying a particular space over a given interval of time.

Populations are the next step up the **systems hierarchy** from the individual organism.

Population structure is the relative proportion of individuals within each stage, e.g., eggs, larva, juveniles, and adults, or category, e.g., male or female.

A maximum **population size** can be reached for a limited area and time frame, given specific and limited amounts of food, shelter, living space, and other resources. This carrying capacity varies from month to month or even day to day with the seasons and other environmental circumstances.

Population density primarily is a function of three factors: birth rate, death rate, and distribution over time and space.

Each organism occupies only areas that meet its requirements for life. As a result, a population generally has a patchy distribution.

HABITAT—WHERE AN ORGANISM LIVES **Habitat provides factors necessary for survival, such as:** ▸ **Hiding places** ▸ **Nesting and birthing sites** ▸ **Shelter from ambient weather conditions** ▸ **Cover for the growth and survival of shade-tolerant species of vegetation** ▸ **Structural features needed for song perches** ▸ **Food source**

In a general sense, a **habitat** can be thought of as the **"address" of an organism.**

Habitat structure provides much of what is needed to sustain life. Habitats also need to be a particular size and often, of a particular configuration to meet the living requirements of a particular species. Habitat size and shape will vary depending on the quality of the habitat and the requirements of the species.

- For example, species that live at the edge of forests (transitional belts between the interior forest and a different adjacent landscape) require a much different habitat type than interior forest species.
- For forest interior plants, the minimum area depends on the size at which moisture and light conditions become sufficient enough to support shade-tolerant species.

Terrestrial habitats are often described in terms of vegetational type, such as a pine forest or a grassland.

Freshwater habitats are broadly classified as standing water or running water.

Literally standing between freshwater and marine habitats, and heavily influenced by both, are **estuarine habitats.**

Marine habitats are generally classified as coastal and open ocean.

COMMUNITIES

Populations of different species live and interact with one another in complex associations called communities.

A **community** is an organized **assemblage or association of populations** in a prescribed area or a specific habitat (Howell, 1994). No species in nature exists in isolation from all others. Communities, more specifically **biotic communities**, are associations of interacting populations and are often defined by the nature of their interactions or by their location.

Communities can be considered on both large- and small-scale levels. Since most species are distributed independently according to environmental gradients (e.g., moisture or light levels, temperature, etc.), no clear-cut boundaries delineate communities. A community could be identified as existing within an entire forest or as existing within a hollow tree. Other examples of small-scale communities could be a decaying log, a pile of dead leaves, or the gut of a deer. The adaptations of populations to their habitats, and the interactions between and among populations determine the nature of a community.

Each community is composed of certain organisms that are characteristic of particular habitats. For example:

- Egrets in salt marsh habitats in eastern North America;
- Saguaro cactus in desert habitats in the southwestern United States; or
- Cattails in freshwater marshes.

Although the species within a community are, to some extent, replaceable by others over space and time, their **functions** in the community are relatively fixed.

NICHE

A niche is the role or function of a species in a community.

Ecological niche is the role or function of a species in its community. The niche is the expression of the relationship of an individual organism or population to the rest of the community.

An organism's ecological niche is expressed as its **"job" in its give-and-take with its environment**. More specifically, an animal's activity pattern, its feeding location, and its place in a food web—what it eats and what eats it—contribute to a description of its niche. For example:

- Red-eyed vireos hunt for food in trees; ovenbirds hunt on the ground.

- Red-tailed hawks are active by day; screech owls are active at night.

Some birds of related species within the same family occupy separate niches in parts of the same kind of tree.

- Bay-breasted, blackburnian, black-throated green, cape may, and yellow-rumpled warblers each live in a different zone or part of a spruce tree. Each species nests in a different part of the tree and at a different height above the ground. Each species gathers insects in a different part of the tree. These birds sometimes overlap in the *physical space* they occupy in or about the tree, but their *niches* do not (Terres, 1980).

This example points out the importance of the diversity of species. Each species performs a particular function, and the loss of a species will disrupt the community. This becomes especially important when endangered species are at risk, because there is little or no reserve capacity for those species to fill vacated niches and maintain community function.

Plants may form niches according to light levels. For example, in a tropical rain forest different plants live at different heights—canopy (tall trees), understory trees, shrub layer, and ground layer of vegetation. Plants living in each layer of the forest have adapted to different light levels.

SUCCESSION

The gradual replacement of one community by another as environmental conditions change.

Communities exist in a continual state of flux. Organisms die and others are born to take their place. When a habitat is disturbed—for example, by clear cutting, fire, or hurricane—the community slowly rebuilds. The sequence of changes initiated by disturbance is called **succession**. The creation of any new habitat—a plowed field, a temporary pond left by heavy rains—invites a host of species particularly adapted to be good pioneers, or to colonize the newly disturbed sites.

Succession is the process whereby the pioneering species adapted to the disturbed habitat are progressively replaced by other species, and so on, until the community reaches its former structure and composition. For example, consider the following sequence of events:

- An oak-hickory community is burned.
- Annual and perennial herbs (pioneers) invade that area.
- Pine seeds blow in.
- The pines and herbs compete for resources.
- Within 30 years, the burned area has become a stand of pines.
- The forest floor (under the pines) shows many oak and hickory seedlings (pine seedlings grow poorly in shade while competing for nutrients).
- A well-developed oak-hickory understory exists within 50 years.
- Oaks and hickories replace the pines as they die.
- Within 200 years, the burned area once again becomes an oak-hickory forest.

This example illustrates that the microenvironment beneath a plant community differs significantly from that in the open. Temperature, humidity, soil moisture, and light are all affected by the canopy.

- A stable community consists of species whose seedlings can survive in its unique microenvironment while seedlings of other species cannot.

Succession (Continued)

- If the stable community is removed by some disturbance, leaving the soil exposed to full sunlight, the first species that colonize the site are not those of the old community; rather, they are seedlings of species adapted to grow in full light intensity.

Succession has been classified into two types (primary, secondary) according to its origin. The terminal community is known as the climax, although subtle changes in species composition continue after reaching the climax growth form. **Primary succession** is the establishment and development of plant communities in newly formed habitats previously without plants. **Secondary succession** is the return of an area to its natural vegetation following a major disturbance. The characteristics of the dominant species change during succession:

- Early-stage species are opportunistic, and capitalize on their high dispersal ability to colonize newly created or disturbed habitats rapidly. These species, which include dandelions and milkweed, typically have small wind-dispersed seeds. The seeds can remain dormant in soils of forested or shrub-covered areas for years until fire or treefalls create the bare soil conditions they need for germination and growth of the early-stage species.

- Climax species disperse and grow more slowly. Their shade tolerance as seedlings, and large size as mature plants give them a competitive edge over early successional species.

It should be noted that communities do not always return to the climax state following a disturbance, especially if there is an increasing impact of humans on the environment. In some cases, humans might have modified an area so extensively that the natural disturbance and succession regimes can no longer exist.

An example can be seen in some of the southwestern portions of the United States, as well as the many other arid or semi-arid regions of the world. In these areas, where local climates would normally allow grassland to maintain itself, the influence of disturbances, such as overgrazing by livestock, have led to the long-term conversion of productive, arable grassland to desert. The same community in a region with a true desert climate would be a natural condition; however, in "desertified" regions it can be seen as a "disclimax"—a disturbance-caused climax community.

PRINCIPLES OF EVOLUTION

- **No two individuals are exactly alike**
- **There is competition for survival**
- **Some individuals have traits better suited for survival in a particular environment**

Evolution consists of changes in the genetic makeup of a population over time. This process occurs because of several facts:

- All organisms show **variation**—no two individuals are exactly alike.
- All organisms **produce more offspring than can survive** to adulthood.
- There is **competition** for survival within and among species or populations for energy, sunlight, food, nutrients, water, space, and mates.
- Under given conditions, **individuals with certain characteristics have a better chance of survival and reproduction** than others because they can use the environment to better advantage.
- Some of those **characteristics are inheritable** over long time spans—geologic time or less.

The result is **natural selection**. The commonly used phrase to describe natural selection is "survival of the fittest." However, this refers to genetic lines and not individuals. Fighting for survival is only a small part of competition in natural selection.

- Darwin's finches on the Galapagos Islands of the Pacific developed a great variety of bill shapes, behaviors, and other features to facilitate feeding on different types of food (bugs, seeds, flowers, etc.). These characteristics were developed to adapt to various environmental conditions, such as temperature, moisture, chemistry, light, etc.

Principles of Evolution (Continued)

Artificial selection is the intentional breeding of a species such as livestock, pets, plants, etc. It may also be the unintentional spread of a species or characteristics, such as resistance of insects to pesticides, or bacteria to antibiotics. This results in very complex, self-sustaining communities finely adapted to the environment in which they live. When it is that finely tuned, disturbances to the environment can have a tremendous impact, from which they may or may not recover.

For most of its history, the human species was subject to the forces of natural selection. This has changed for several reasons:

- A cultural evolution led to technology, freeing humans to a great extent from the effects of natural selection.

- Humans are still part of ecosystems, but we are now almost always the dominant factor, subjecting other species to an array of stresses to which they are not adapted.

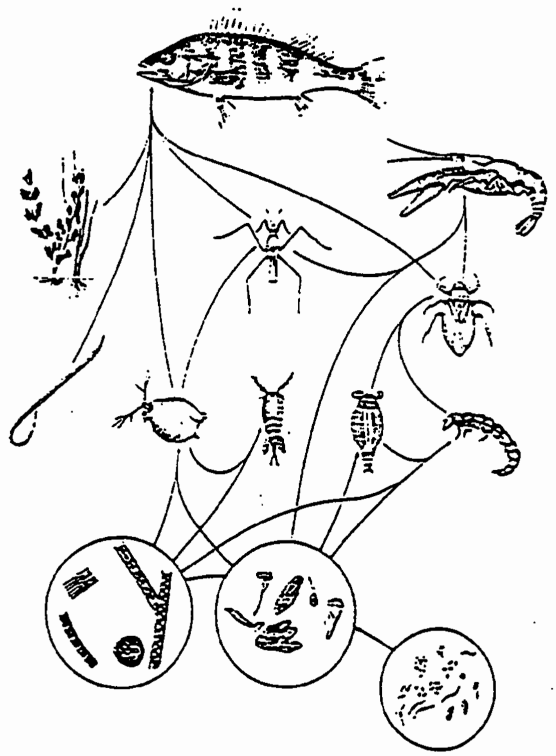
- For many species, even communities, the rate of introduction of new human stressors (physical, chemical or biological) far outstrips the rate with which they can evolve adaptations.

- A shift is occurring on the planet from self-sustaining communities that have evolved over very, very long periods of time, to very recently created communities that require artificial inputs of energy and materials, e.g., agriculture.

If long-term or unprecedented environmental changes occur, the response by a species or population will be:

- Extinction;
- Survival unchanged; or
- Evolution or adaptation.

FOOD WEB



Food Web

A **food chain** is the transfer of energy from one species to another. However, no organism lives wholly on another, and many organisms share several different food sources. Consequently, food chains interlink and form **food webs** (see diagram).

The term food web more accurately describes the **complex, interrelated system of pathways** through which the flow of energy takes place in nature. A food web is the total set of feeding relationships among and between species.

Food Web (Continued)

The food web hierarchy is described by **feeding, or trophic, levels**:

- **Producers**—Producers, primarily green plants, are the trophic level that supports all others.

- **Consumers**—Consumers rely on producers as an energy source. Most consumers belong to one of three groups:

  - **Herbivores**, which consume plants.
  - **Carnivores**, which consume meat.
  - **Omnivores**, which consume both meat and plants.

Many species are omnivores, living on mixed diets of plant and animal material. For example, black bears feed on berries, nuts, insects, rodents, and other plant and animal material.

Many species **change their feeding habits seasonally** or have different food requirements at different life stages. For example, seeds, nuts, and acorns are staple food items for turkeys during most of the year, but in summer, turkeys eat grasshoppers, other insects, frogs, toads, snakes, and other animals.

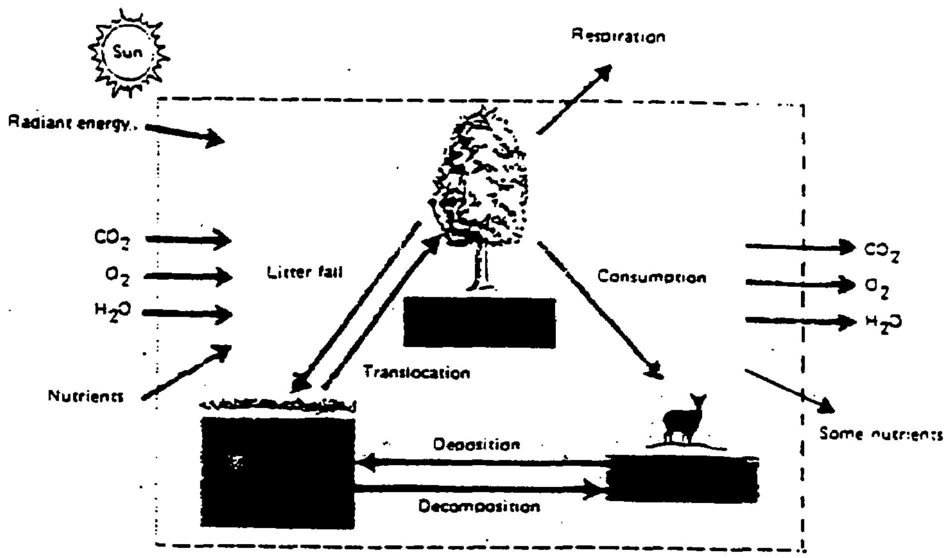
Trophic Levels and Energy Level

Consumers can be categorized into trophic levels. All organisms that share the same general source of nutrition are said to be at the same trophic level. Consumers belonging to more than one trophic level are called omnivores.

Energy decreases as trophic levels increase—at each step in the food chain, energy is lost in respiration, and less energy is available for the next level up. Caloric energy stored by plants is passed through the community through successive transfers between plants and herbivores, and prey and predators. At each step in the food chain, a considerable portion of the potential energy transferred in the food is lost as heat. The longer the food chain, the more restricted the amount of energy that will reach the terminal members. As a result, we rarely find food chains of more than four or five steps in natural situations. Furthermore, the number of organisms involved in the populations through which this energy passes becomes smaller with each new link.

ECOSYSTEM

Generalized ecosystem diagram illustrating the systematic nature of ecosystems and major components of the system



An **ecosystem** includes the **physical environment** and its **component plant and animal populations**. In the simplest of terms, all ecosystems consist of **three basic components**: the producers, the consumers, and abiotic (or nonliving) matter (Smith, 1990).

- Producers and consumers make up the **biotic (or living)** components of an ecosystem and include plants, algae, bacteria, and animals. As covered previously, populations of these organisms grouped into recognizable aggregations are known as communities.

- **Producers** are the energy-capturing base of the system. Producers are largely **green plants** that are able to fix (or transform) the energy of the sun and manufacture food from simple inorganic and organic substances.

Ecosystem (Continued)

- **Consumers** use (eat) the food stored by the producers, rearrange it (through digestion), and finally decompose the complex materials into simple, inorganic substances (assimilation into body tissues).

The structural elements of an ecosystem are the species, population, community, habitat, and food chain. The functional elements include niche and the flow of energy through the system's producers and consumers.

ABIOTIC FACTORS

Soils, sediment, water, solar radiation, nutrients, and minerals.

Ecosystems are not closed systems, existing within neatly defined boundaries. For example, picture a stream flowing through a deciduous forest, then a grassland, then, gradually, a salt marsh, ultimately emptying into a bay. Obvious **gradations exist** along this kind of continuum, yet the **ecosystems are identifiable by general landscape characteristics.**

The **elements that differentiate ecosystems** are abiotic components that make up the physical environment, such as soils, sediment, water (moisture, salinity), solar radiation, and nutrients. These elements determine the types of organisms that can inhabit a particular ecosystem.

PHOTOSYNTHESIS

The process by which plants convert light energy into chemical energy, which is stored as glucose.

Ecosystems operate because light energy from the sun is absorbed by **photosynthetic organisms** (plants, algae, and photosynthetic bacteria) and transformed into chemical energy in the form of glucose.

- Glucose is a sugar and an organic compound. Compounds that contain carbon and hydrogen are called organic compounds. The glucose is used to synthesize (or produce) carbohydrates, amino acids, proteins, fatty acids, fats, vitamins, pigments, etc.

Non-photosynthetic organisms (i.e., animals) get energy by eating this sugar or other substances, such as carbohydrates, that the plants make from it.

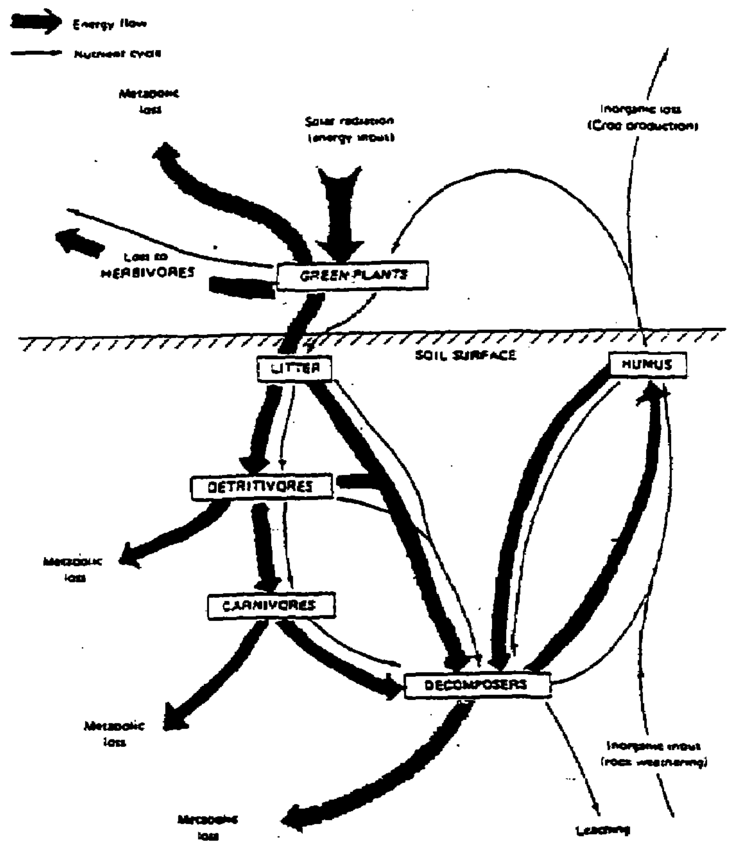
- When an animal eats a plant, the animal gets energy and the carbon-compound that is storing the energy. The animal uses the compound as a source of carbon to synthesize the substances it needs. In other words, photosynthesis is important for generating both energy and essential substances in an ecosystem.

Photosynthetic organisms are **producers**, and non-photosynthetic organisms are **consumers** (because they must consume producers to obtain energy).

In summary, organisms need energy to survive, and they need a source of carbon in order to synthesize carbon-containing substances, such as proteins and fats.

- Photosynthesis supplies both needs by converting light energy into chemical energy, and by combining carbon dioxide (CO_2) gas and water to form glucose, an organic compound. Glucose, then, is a source of energy and organic carbon for making all the other substances organisms need for survival.

DECOMPOSITION



Decomposition

Organisms living in any ecosystem require a continual supply of **energy** and **nutrients** in order to survive. Photosynthesis provides the energy, and decomposition provides the nutrients.

Decomposition of organic matter, such as what occurs to fallen leaves and logs, or roadkilled possums, consists of breaking down organic compounds and returning basic chemical elements, such as carbon, to the soil. The organisms most commonly associated with decomposition are bacteria and fungi. These microorganisms secrete enzymes into plant and animal matter, causing them to decompose.

- Bacteria are the major decomposers of animal matter.
- Fungi are the major decomposers of plant material.

Once one group has exploited the material to its capabilities, another group of bacteria and fungi able to use the remaining material move in. In this way, a succession of microorganisms acts on the organic material until it is finally reduced to inorganic nutrients. Detritivores are invertebrates that aid decomposition by fragmenting leaf litter, etc. Examples of detritivores, from smallest to largest size, are as follows:

- Protozoans;
- Mites, springtails, potworms;
- Nematodes, caddisfly larvae, mayfly nymphs; and
- Snails, earthworms, millipedes.

NUTRIENTS AND BIOGEOCHEMICAL CYCLES

Nutrients are essential to plants and animals and are used over and over again, cycling between organisms and the environment.

For an ecosystem to function, nutrients must be available to plants, and must be present in a consumer's diet. Of the many elements required, these eight are the most important:

- Carbon: A basic part of all organic compounds, such as glucose. In the ecosystem, it exists as carbon dioxide, carbonates, and fossil fuel, and as a part of living tissue.
- Hydrogen: Also a basic part of organic compounds and an important component of water.
- Oxygen: A by-product of photosynthesis. It is used by microbes in the decomposition process, and is used by animals in cellular respiration. Three major sources of oxygen are carbon dioxide, water, and molecular oxygen.
- Nitrogen: An essential element of protein and DNA. It makes up about 79% of the atmosphere as molecular nitrogen, but most plants can use it in a changed form, such as nitrates or nitrites.
- Phosphorus: An element involved in photosynthesis. It plays a major role in energy transfer in plants and animals.
- Sulfur: Like nitrogen, a basic constituent of protein.
- Calcium: Element necessary for proper acid-base relationships, blood clotting, contraction and relaxation of the heart muscle, etc.
- Magnesium: Element that helps certain enzymes function and is crucial to protein synthesis in plants.

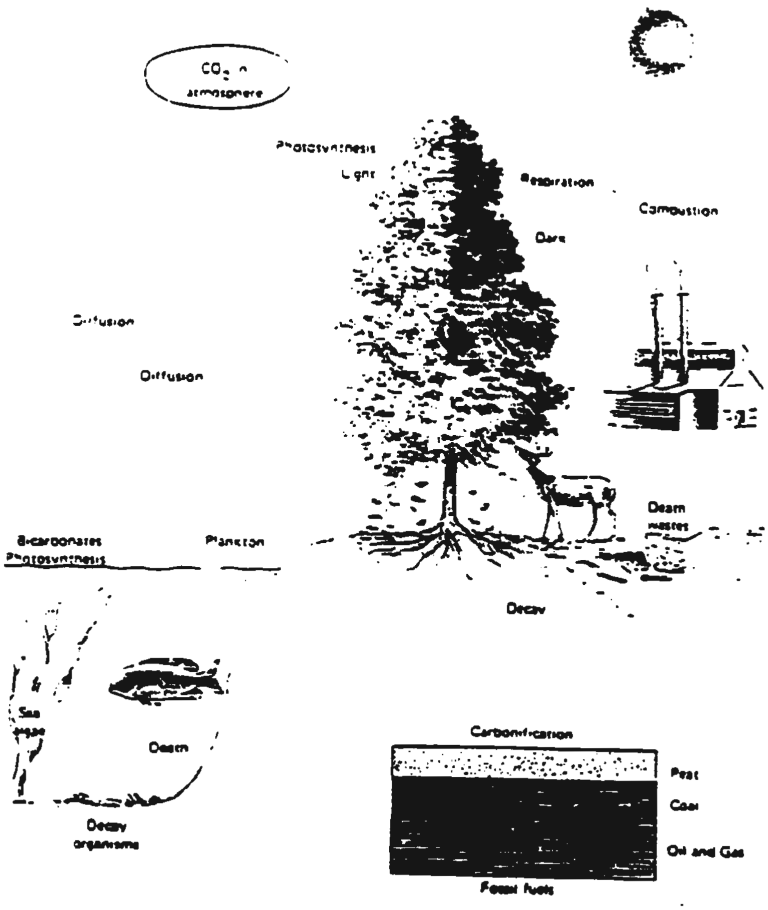
Nutrients and Biogeochemical Cycles (Continued)

These chemical elements are not destroyed upon the death of an organism. They can be used over and over again, being transferred from organisms to the environment and back to the organisms, in more or less circular paths, called **cycles**. Each element that is a nutrient follows its own unique pathway, called a **biogeochemical cycle** or **nutrient cycle**, through the abiotic and biotic components of an ecosystem.

In contrast to energy, which is in constant supply from the sun, nutrients exist on earth in fixed amounts. Life evolved the means to use mineral nutrients, release them to the abiotic environment, and then use them again. Although energy eventually leaves the earth as heat, and nutrients remain on earth to be recycled, the pathways of both are closely tied together. For some nutrients, going back and forth between the physical environmental and living organisms entails changing from an inorganic element or compound to an organic compound.

The **nitrogen cycle** is one specific example of the many biogeochemical cycles. Gaseous nitrogen is converted into ammonia, nitrates and nitrites by specific microorganisms. Plants convert these nutrients into proteins, DNA, and other organic compounds. Animals obtain these nutrients by eating plants or other animals. When plants and animals die, certain decomposer bacteria convert the nitrogen-containing organic compounds back into ammonia, nitrates, nitrites, and gaseous nitrogen beginning the cycle over again.

CARBON CYCLE



Carbon Cycle

The **carbon cycle** is another critical biogeochemical cycle. The recycling of carbon between the abiotic and biotic elements of an ecosystem is linked inseparably to the flow of energy through photosynthesis and respiration. The abiotic part of the carbon cycle involves carbon dioxide, a gas that makes up a small percentage of the atmosphere (0.03 percent) and is dissolved in the waters of the earth.

- Producers convert solar energy into chemical energy, which they use to convert the carbon in carbon dioxide into glucose.
- As plants respire (at night), they convert some of the carbon in organic compounds back to carbon dioxide, which is released into the environment.
- The rest of the converted carbon is stored in new plant tissue, which is transferred along a food chain.
- At each link in the food chain, more of the carbon converted by the producer is released by a consumer as carbon dioxide.
- The release of converted carbon by respiration replaces much of the carbon incorporated into glucose during photosynthesis.
- In breaking down organic waste and dead organisms, detritivores and bacteria return carbon to the physical environment in the form of carbon dioxide.

MAJOR TYPES OF ECOSYSTEMS

Terrestrial: **Grasslands, deserts, coniferous forests, deciduous forests, alpine, tundra, rainforest**

Aquatic: **Lakes and ponds, streams and rivers, wetlands, estuaries, open sea**

There are two major types of ecosystems: terrestrial and aquatic.

Examples of terrestrial ecosystems include:

▸ Rainforest	Amazon, northeastern Australia
▸ Deserts	Mojave and Sahara
▸ Grasslands	Serengeti, Great Plains of the U.S.
▸ Deciduous Forests	New England maples, Colorado aspens
▸ Coniferous Forests	Rocky Mountains, Mt. St. Helens
▸ Alpine	Swiss Alps
▸ Tundra	Greenland, Siberia

Aquatic ecosystems—freshwater and saltwater—include the following:

▸ Lakes and Ponds	Great Lakes, Walden Pond
▸ Streams and Rivers	Ohio River
▸ Wetlands	Florida Everglades
▸ Estuaries	Chesapeake Bay
▸ Open Sea	Pacific Ocean
▸ Coral Reefs	Australian Great Barrier Reef

ECOLOGICAL EFFECTS
of STRESSORS

- Stressor Types
- Kinds of Ecological Effects
- Factors Influencing Ecological Effects

Ecological Effects of Stressors

We just concluded a discussion of a few basic terms and concepts necessary to develop a cursory understanding of the fundamentals of ecology. This section continues in the same manner by providing an overview of the characteristics of man-made or anthropogenic stressors and their ecological effects.

A definition and description of the types of stressors that commonly are addressed during an ecological risk assessment will be provided. Such stressors are those we (humans) have control over.

Next, we will discuss some stressor characteristics, followed by examples of the kinds of ecological effects caused by stressors.

The section concludes with a brief discussion of the ecological significance of the effects caused by anthropogenic stressors.

STRESSOR TYPES

▸ Chemical Stressors	Industrial chemicals, pesticides, fertilizers, smog, auto exhaust, radionuclides, etc.
▸ Physical Stressors	Logging, dredging/filling wetlands, road construction, etc.
▸ Biological Stressors	Introduced organisms and microorganisms such as starlings, gypsy moths, multiflora rose, genetically engineered microorganisms, etc.

Ecological risk assessments evaluate the **effects** caused by three general types (or categories) of **stressors**–chemical, physical, and biological.

Chemical stressors include hazardous waste, industrial chemicals, pesticides, and fertilizers. These stressors are by far the most frequently investigated during ecological risk assessments. This is evident in the focus of most of the major pieces of environmental legislation and the EPA programs developed to enforce such legislation. For example,

- CERCLA—Uncontrolled hazardous waste (Superfund).
- RCRA—Controlled hazardous waste.
- FIFRA—Pesticide registration.
- TSCA—Manufacture and use of toxic substances.
- CWA—Discharge from municipal wastewater treatment plants and industrial facilities.

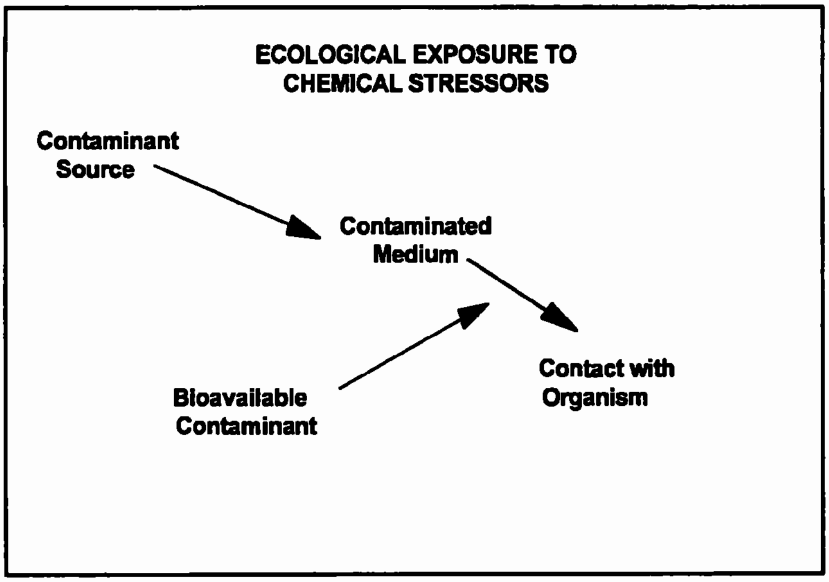
Physical stressors are activities that directly remove or alter habitat. Ranging from tilling soil to logging, road construction, and the building of shopping malls, these stressors often are the most destructive because they can result in total habitat loss as soils are compacted and organisms are lost.

EPA's regulatory authority with regard to physical stressors pertains to filling waters of the U.S. including wetlands (Section 404 of CWA), e.g., placing fill in water for constructing a bulkhead to shore-up waterfront property.

Biological stressors are organisms or microorganisms that are introduced, or released, (intentionally or accidentally) to habitats in which they did not evolve naturally. These organisms often are called "exotics." Biological stressors become a concern when they compete against native species, replace them, and become pests.

Stressor Types (Continued)

With regard to ecological concerns, **EPA's jurisdiction** over biological stressors is limited essentially to the regulation of **genetically engineered microorganisms** under the auspices of FIFRA and TSCA (for use in commerce). The federal agencies primarily responsible for regulating exotics are the U.S. Department of Agriculture and the U.S. Fish and Wildlife Service.



Exposure is the route and extent of contact between a **chemical stressor** and the ecological component. Exposure includes three aspects:

- *The chemical must reach the organism.* This means that some medium must be contaminated, such as air, water, soil, sediment, or other organisms.

- *The chemical must be in a form that can cause effects.* This is known as **bioavailability**.

- *The chemical must reach a site on or in the organism where the chemical can cause effects.* This means that the organism must breathe, eat, drink, touch, or be touched by the contaminated medium.

Depending on the physical and chemical properties of contaminants, they are incorporated into the cycles of the atmosphere, soil, and/or water, where ecological components become exposed. Once in the environment, chemicals can undergo changes and/or move from one medium to another. This is called **fate and transport**.

Chemical stressors can be altered by physical and chemical processes. For example:

- Light energy can alter a substance through a process called **photolysis**.

- Some substances react with water in a process known as **hydrolysis**. To illustrate, acetic anhydride, which is corrosive and causes burns, is hydrolyzed to acetic acid (vinegar), a food substance.

Exposure (Continued)

- Contaminants can react with other chemicals in the environment to produce new compounds. For example, under the right conditions lead will bond with sulfide ions in sediment to form an insoluble, nontoxic mineral, lead sulfide (galena).

THE NATURE OF CHEMICAL STRESSORS

Bioavailable chemicals exist in a form that organisms can take up.

No bioavailability equals no uptake and therefore no effect.

Before a chemical stressor can induce an effect in an organism or become incorporated into its tissues, the **chemical stressor must be bioavailable.** That is to say, it must exist in a form that the organism will absorb.

The **total amount of a substance** detected in contaminated media **is not necessarily bioavailable.** A portion of the chemical stressor might be sorbed (or adhered) to soil or sediment particles, or to particles suspended in the water column or atmosphere. Some or all of the chemical might be chemically bound as an insoluble salt or other biologically unavailable compound.

- Only the bioavailable portion of the total amount of contaminant in the environment is relevant to an ecotoxicity evaluation. **No bioavailability equals no uptake and therefore no effect.**

- The **bioavailability** of a substance can **change with changes in environmental conditions.** For example, an increase in the acidity of water or soil can increase the bioavailability of metals.

Biologically unavailable chemical stressors in ingested soil, sediment, or water may **become bioavailable during the digestive process.** For example, a squirrel might inadvertently ingest lead-contaminated soil in the process of opening an acorn. If the lead in the soil is not bioavailable (i.e., is strongly sorbed to the soil particle), it can become bioavailable when the acid in the squirrel's stomach causes the lead to dissociate (or desorb) from the soil particles. The lead is now available for uptake into the animal's bloodstream.

BIOCONCENTRATION

BIOACCUMULATION

BIOMAGNIFICATION

When evaluating the potential for toxic effects from chemical stressors, we have to consider bioconcentration, bioaccumulation, and biomagnification as factors. Note that these are **factors, not effects**. Even if a chemical stressor is present at low concentrations in the environment, it might still pose a threat to ecological components if it bioconcentrates or bioaccumulates, and especially if it biomagnifies.

Bioconcentration - The absorption of a chemical by an organism to levels greater than the surrounding environment.

Bioaccumulation - Uptake and retention of a chemical by an organism through feeding and bioconcentration.

Biomagnification - Increased concentration as a contaminant passes up the food chain.

A classic case of biomagnification is DDT. During the years of its use, the pesticide DDT caused eggshell thinning in numerous birds of prey, including hawks and eagles. DDT occurred at low concentrations in water as a result of runoff from agricultural fields. Because DDT is very persistent and because it accumulates in fat tissue, it biomagnified in the food chain, beginning with aquatic plants and invertebrates, through fish, to fish-eating birds. The lower concentrations occurring at the bottom of the food chain produced no adverse effects, but the high concentrations in the birds caused eggshell thinning and reduced reproductive success.

Bioconcentration, Bioaccumulation, Biomagnification (Continued)

A **bioconcentration factor** (BCF) is the concentration of the chemical in the organism, divided by the exposure concentration. It is often used in ecological risk assessments to help characterize exposure.

BCFs for *Daphnia magna* (Water Flea)

Substance	BCF
Benzo(a)pyrene	12762
Bis(2-ethylhexyl)phthalate	5200
Manganese chloride	911

Bioconcentration varies among chemicals. Bioconcentration, bioaccumulation, and biomagnification depend on both the chemical and the species exposed to the chemical. As shown in the above table, bioconcentration in one species varies with the chemical. Also, bioconcentration of the same chemical varies with the species. Environmental conditions also affect bioconcentration and bioaccumulation, so in site-specific risk assessments, we may sometimes want to calculate site-specific bioconcentration factors.

THE NATURE OF PHYSICAL STRESSORS

The severity of the impact of a physical stressor depends primarily upon:

- **The size of the affected area.**
- **The frequency of the disturbance.**
- **The intensity, or physical force, of the distributing event.**

All **ecosystems** are **dynamic** and possess some degree of **resilience** to recover from a disturbance. Natural disturbance is a normal part of ecosystem functioning. Occasional disturbances that cause fluctuations in community structure and function are as much a part of natural processes as is the cycling of nutrients. However, the addition of human-caused physical stressors often pushes a system's resilience to its limits because they tend to be more frequent, more intense, and tend to impact larger areas than do natural disturbances. In other words, they represent new types of disturbances to which the system has not evolved adaptations.

The extent to which this combination is overwhelming depends on the **size** of the affected **area**, the **frequency of disturbance**, and the **intensity of the disturbing event**. Generally speaking, larger and more frequent physical stressors result in more extensive and longer-lasting effects. Massive and intensive disturbances can sometimes take centuries to recover. Sometimes recovery is apparent within years, a relatively short period of time.

- Whether a two-lane country road or a superhighway, road construction means **habitat loss**. Often wetlands are filled, hilltops are removed, and other changes are made. The movement of heavy machinery results in the compaction of soil. During construction, rain washes exposed soil into streams and other bodies of water. Also, use of the road will introduce some **chemical stressors**, such as oil and gas residues, and road salt in northern climates.

- **Surface mining** removes habitat and increases erosion. Removing topsoil often exposes iron- and sulfur-bearing strata to rain, resulting in highly **acidic runoff** that renders nearby water bodies lifeless. Surface mining also exposes water tables, adding to the volume of runoff.

The Nature of Physical Stressors (Continued)

- **Clear-cutting**, a common form of timber harvesting, removes large blocks of forested habitat. The erosion associated with logging occurs both from the newly exposed forest floor and from improperly constructed logging roads.

- Clearing and plowing fields for **agriculture** disturbs the structure of the soil, exposing it to erosion by water and wind. Water erosion often carries soil, fertilizers, and pesticides to nearby streams and rivers.

THE NATURE OF BIOLOGICAL STRESSORS

Biological stressors are living organisms (including microorganisms) accidentally or intentionally introduced to an ecosystem.

Unlike chemical and physical stressors, biological stressors can reproduce, adapt, and spread, adding new dimensions to the ecological assessment process.

Biological stressors are known as "**exotics**" because they have not evolved along with the organisms that make up a particular biotic community.

These **stressors** add another dimension to the ecological risk assessment process because they are **living and reproducing organisms** that require the consideration of active biological and mechanical transport, passive transport, or both.

- Microorganisms, some invertebrates, and some seeds have nearly the same capability for transport; they are carried in the guts of animals, by wind, and by water.
- Mechanical transport (e.g., ships, trucks, airplanes) is as effective as biological transport in moving organisms over long distances. Upon arrival in a suitable habitat, biological stressors use nutrient and energy sources to grow and reproduce.

KINDS OF EFFECTS CAUSED BY CHEMICAL STRESSORS

- **Organism Level—Mortality, behavioral changes, physiological impairment (e.g., growth, reproduction).**
- **Population Level—Decreased birth rates, increased mortality rates, increased dispersion, local extinction.**
- **Community/Ecosystem Level—Structural changes (e.g., population loss), functional changes (e.g., niche loss), habitat destruction.**

Effects are measured and evaluated in terms of organisms, populations, communities, and ecosystems. For the most part, community-level effects translate into ecosystem effects, because communities make up the biological portion of an ecosystem.

Organism Level. Chemical stressors matter because of their effects on populations, and, indirectly, on communities, but chemical stressors act by their immediate effects on individual organisms (Moriarty, 1983). Effects on individuals range from **rapid death through sublethal effects** to no observable effects. These effects may be indirect, occurring as a result of elimination of prey base or habitat alteration. In the case of threatened and endangered species, effects influencing a few individuals are likely to be significant because they are at or near to the point of no return.

Population Level. Usually, effects become ecologically significant when they affect the survival, productivity, or function of a significant number of individuals such that **population size is reduced, population structure is altered, or total function is impaired** (Cockerham and Shane, 1994).

- **Population size** can be reduced if stressors reduce mating success or egg production; reduce survival of offspring or reproductive-age adults; increase susceptibility to predation, parasitism, and disease; affect recruitment through altered immigration or emigration rates; or reduce development or maturation rates.
- **Population structure** can be altered if stressors differentially affect one age group or developmental stage, reduce development or maturation rates, or differentially affect one sex.
- **Ecological function** can be reduced if stressors impair photosynthesis, reduce organisms' efficiency in converting food into energy, or cause organisms to slow or stop performing activities such as decomposition of leaf litter or fixation of nitrogen.

Kinds of Effects Caused by Chemical Stressors (Continued)

Community/Ecosystem Level. Community/ecosystem-level effects are often the direct result of stressors affecting the ability of populations to interact with one another.

Two examples of a stressor affecting a population's ability to interact with other populations are an **impaired ability to avoid predators** and a **decreased ability to prey on lower trophic levels.**

A population can suffer from indirect effects due to a stressor altering the dynamics of populations with which it interacts, such as reduction in the abundance of a predator due to toxic effects on prey.

Stressors can result in changes in **structural** properties of a community, such as the **number of species or trophic levels,** or changes in the functional properties of an ecosystem, such as photosynthesis.

Lethal and Sublethal Effects

Adverse effects on living organisms can be either lethal or sublethal.

- Lethal—Mortality of individuals due to exposure to chemical stressors.
- Sublethal—Other adverse effects. These include reproductive impairment, disruption of certain functions such as growth or photosynthesis, and induction of behavioral abnormalities such as hyper- or hypo-activity.

Frequently, the type of sublethal effect is characteristic of the chemical stressor of concern. For instance, lead and mercury are associated with behavioral abnormalities in mammals.

Toxicity varies among chemicals. Toxicologists measure the lethal effects of a chemical by exposing test animals to various concentrations or doses of the chemical and counting how many organisms die in a specified period of time.

Kinds of Effects Caused by Chemical Stressors (Continued)

Lethality is usually expressed as the median lethal concentration or dose (LC_{50} or LD_{50}) which is the concentration or dose at which 50 percent of an exposed population dies. Notice that the lower the LC_{50} or LD_{50}, the more toxic is the chemical. It takes less to kill 50 percent of the population. As the table shows, lethal concentrations vary among chemicals for a particular species.

Lethal effects are measured by **Median Lethal Concentration (LC_{50})** and **Median Lethal Dose (LD_{50})**.

LC_{50}s for *Daphnia magna*	
Substance	LC_{50}
Aroclor 1248	2.6
Cadmium chloride	65
Carbon disulfide	2100
Sodium arsenite	5278

As with lethal effects, ecotoxicologists test for sublethal effects by exposing organisms to different concentrations or doses of a chemical, and counting how many exhibit the adverse effect. Sublethal effects are frequently reported as follows:

- **Median effects concentrations or doses (EC_{50}s or ED_{50}s)** indicate the exposure at which 50 percent of exposed organisms exhibited the effect being evaluated by the investigation.
- **Lowest Observed Adverse Effects Level** or **Concentrations (LOAELs** or **LOAECs)** indicate the lowest exposure at which adverse effects were initially observed.
- **No Observed Adverse Effect Levels** or **Concentrations (NOAELs** or **NOAECs)** indicate the highest exposure at which effects were not observed.

Sometimes the word "adverse" is left out, making these acronyms LOEL or LOEC and NOEL or NOEC. The following tables show how sublethal effects vary according to the chemical, the species, and the effect.

Kinds of Effects Caused by Chemical Stressors (Continued)

LOAECs for Phenanthrene

Species/Effects	LOAEC (in µg/l)
Daphnia pulex/reproduction	110
Daphnia pulex/growth	360
Selenastrum capricornutum (alga)/population growth	800,000

LOAECs for Di-n-octyl phthalate in Fathead Minnows

Effect	LOAEC (in µg/l)
Reduced Growth	8300
Reduced Hatching	1760

CHEMICAL STRESSORS:
AN EXAMPLE

Nutrient Loading (Eutrophication)

The biological overproduction in aquatic ecosystems primarily as a result of increased nitrogen and phosphorus from agricultural drainage, partially treated sewage and other wastes, etc.

Images of hazardous waste come to mind first when considering chemical stressors. However, there are other kinds of chemical stressors that are widespread and more damaging in terms of ecological impacts. One example is **nutrient loading or eutrophication,** which is the biological overproduction in aquatic ecosystems.

Treated sewage, drainage from agricultural lands, river basin development, runoff from urban areas, and other factors, commonly increase the rate of nitrogen and phosphorus loading to aquatic ecosystems, and are the major causes of **biological overproduction, or eutrophication.**

Nitrogen and phosphorus are required in limited amounts by algae and aquatic plants. However, excess amounts of these nutrients act as fertilizers and cause photosynthetic rates to increase dramatically. The corresponding growth forms dense algal populations, increases turbidity and sedimentation, reduces the lighted region where photosynthesis occurs, and prevents the growth of submerged aquatic vegetation.

Increased sedimentation reduces growth rates or resistance to disease, prevents successful development of eggs and larvae, modifies natural movement or migration patterns, reduces the natural availability of food, and results in more oxygen being consumed in the lower reaches of the water column and the sediments during the decomposition of organic matter. The result often is a **depletion** or almost complete absence of **dissolved oxygen** in the lower reaches of the water column.

CHEMICAL STRESSORS:
ANOTHER EXAMPLE

Acid Deposition

The release of sulfur dioxide and nitrogen oxide to the atmosphere (primarily as a result of fossil fuel combustion), where they form sulfuric and nitric acid, which then falls back to earth in all forms of precipitation.

The **major industrial sources** of acid deposition are internal combustion engine, utility plants, etc. These industrial sources produce **sulfur dioxide and nitrogen oxides** which are the precursors of acid deposition. These substances readily react in aerosols to generate sulfuric and nitric acid, respectively. These acids and their precursors are picked up and transported from one locale to others by the prevailing winds. Deposition then occurs in precipitation in all its forms.

Eighty percent of sulfur dioxide released into the atmosphere is attributed to human activity—100 percent in some regions. Of that, 85 percent is attributed to fossil fuel combustion. Nitrogen oxides also come from combustion, the most notable source being motor vehicles.

For **terrestrial ecosystems**, the effects of acid deposition have been implicated in declines and **die-back in forests**. In **aquatic systems**, changes in pH, or the acidity or alkalinity of a solution, can affect communities of bacteria, algae, invertebrates, and fish, **altering species composition and productivity**, reducing numbers, and impairing reproduction and decomposition. Acidic conditions can mobilize metals from a bound form in which they are largely non-toxic to a free form in which they are toxic and readily available to organisms.

Acid deposition is thought to be the major cause of the destruction of populations of fish and other aquatic organisms in many lakes, particularly in the northeastern United States (Cockerham and Shane, 1994).

KINDS OF EFFECTS CAUSED BY PHYSICAL STRESSORS

Erosion	Removal and transport of soil material by water and wind.
Siltation	Soil that is removed by erosion makes its way to streams and rivers.
Increased Light Intensity	Vegetation removal results in higher soil and water temperature and lower soil moisture and relative humidity.

Disturbances create conditions for **erosion** by destroying plants, their roots, and soil organic matter. Arid and semiarid climates are especially prone to wind erosion. The soil in such areas has little moisture to hold it together, and the small quantity of vegetation that grows in such areas does not provide stems and leaves extensive enough to block the wind, or roots extensive enough to hold soil in place.

Examples of natural causes: Water flow (rivers and streams), heavy rains, flooding, drought followed by rain storms or strong winds.

Examples of man-made causes: Agricultural practices (such as irrigation, plowing, clearing of land, grazing), removal of vegetation (timber harvesting), construction of roads, buildings, etc.

One of the major ecological problems associated with erosion is **siltation**. Siltation results in the deposition of excess soil where stream and river currents are slow, smothering plants and bottom-dwelling organisms, and covering important fish habitat. Some fish, such as salmon, require clean gravel streambeds in which to spawn. For them, the effects of siltation could result in the loss of critical breeding habitat. Salmon lay their eggs in the small spaces between rocks on streambeds. Water circulating around the eggs supplies them with oxygen, which is dissolved in the water. If the spaces become filled with silt, water circulation around the eggs will decrease and the young will fail to develop.

When the **vegetation** along a stream or other water body is removed (e.g., by clear-cutting, house construction, etc.), the amount of sunlight reaching the water increases. As a result, water temperatures can increase significantly, possibly having lethal effects on some of the resident aquatic organisms.

HABITAT FRAGMENTATION

Physical stressors, such as road construction, logging, dredging wetlands, etc., break larger areas of habitat into smaller patches, or fragments.

Habitat fragments can ultimately become so isolated that they function much like islands.

Wildlife corridors are "natural highways" that link habitat fragments, thereby allowing certain species to survive a partial loss of habitat.

In addition to disturbing or destroying the immediate habitat(s), activities such as road construction, logging, dredging wetlands, and agriculture, whittle away piecemeal at larger, relatively intact areas. This results in **habitat fragmentation**, the breaking up of larger areas into smaller patches or fragments of habitat.

When **habitat patches become isolated** from similar habitat by different, relatively inhospitable terrain, they essentially **become islands**.

If fragmentation continues, the remaining area is reduced to a critical size below which the **habitat** will not provide the **requirements** of many of the original species, and a number of them will disappear.

Many species of terrestrial wildlife can live in fragmented habitats only if **corridors** link enough fragments to provide both habitat requirements and interactions with others of the same species to perpetuate viable populations.

KINDS OF EFFECTS CAUSED BY BIOLOGICAL STRESSORS

Introduced organisms act as biological stressors through predation, parasitism, pathogenesis, and competition for resources.

Exotic organisms include domestic species, accidentally introduced species, non-native game and fish species, biocontrol agents, and, quite recently, species modified by bioengineering. Through **competition, predation, and pathogenesis** (disease), exotic organisms have extinguished native species or reduced them, and have drastically changed the character of the invaded communities (Suter, 1993).

- Outbreaks of insects, such as the introduced gypsy moth and spruce budworm, defoliate large areas of forest, which results in the death or reduced growth of affected trees. The degree of gypsy moth mortality can range from 10 to 30 percent in hardwood forests to 100 percent in spruce and fir stands.
- When two introduced species of plankton-feeding fish, the alewife and rainbow smelt, proliferated in Lake Michigan, seven native species of fish with similar food habits declined drastically (Crowder et al., 1981).
- Japanese honeysuckle, a garden escapee, and multiflora rose, widely planted in the past for soil conservation purposes, have invaded old fields and forest edges, crowding out native plants and affecting the structure and composition of animal life.
- Virulent tree diseases have markedly changed the composition of North American forests. The chestnut blight, introduced into North America from Europe, nearly exterminated the American chestnut and removed it as a major component of the forests of eastern North America. With its demise, oaks and birch increased (Smith, 1990).

ECOLOGICAL SIGNIFICANCE OF EFFECTS

- Nature and magnitude of effects
- Spatial and temporal patterns of effects
- Recovery potential

Ecological significance of effects or the types and extent of effects is an important consideration in assessing ecological risk.

Nature and Magnitude of Effects

The **nature** of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area were assesssed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effect will depend on the ecological context, e.g., life history characteristics. Long-lived vertebrates such as large mammals, predatory birds, and whales are more sensitive to mortality imposed on adults that are short-lived, highly fecund (fertile) organisms such as quail and anchovies (Cockerham and Shane, 1994).

Spatial and Temporal Patterns of Effects

Spatial and **temporal** patterns of effects consider whether effects occur on large scales (e.g., acid rain) or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves (e.g., ozone depletion effects on marine ecosystems).

Recovery Potential

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

NATURAL VS. HUMAN STRESSORS AND RECOVERY

It is important to remember that natural disturbances bring about diversity of the landscape. Wind, moving water, drought, fire, and animal activity yield variation in habitats. These natural disturbances also cause changes in the availability of open space for species to colonize. Ecosystems are adapted to disturbances that have occurred with some frequency over the evolutionary history of the ecosystem and will usually eventually recover and return to their original state.

Humans may introduce stressors to which the ecosystem has not been exposed during its evolutionary history (synthetic chemicals, exotic species). Human-caused disturbances are usually more frequent, more intense and impact larger areas. These larger-scale disturbances can have subtle as well as dramatic impacts on a habitat. They often result in a situation that is overwhelming from which the ecosystem never recovers. **Recovery** is sometimes apparent within years. However, a massive and intense disturbance can cause an ecosystem to take centuries to recover. Even then, the original or "natural" ecosystem may never recur.

Key Concepts

- **Ecosystems are complex and dynamic, composed of interacting networks of biotic and abiotic components.**
- **Principal ecological components are species, populations, communities, and ecosystems.**
- **Critical to the function of an ecosystem is the flow of energy and nutrients through the systems's producers and consumers.**

Key Concepts (Continued)

- **Stressors can affect individual organisms, population growth, community structure and function, and ecosystem processes.**
- **Interactions among individuals in a population, and among populations in a community influence the significance of a stressor's ecological effects.**
- **The combination of stressor, environmental, and biological characteristics dictates the nature, extent, and magnitude of ecological**

Optional Exercise:

The following exercise illustrates how stressors affect a population.

A SIMPLE SIMULATION MODEL
Hypothetical What-If Population

Stage	Initial Number	Maturation Time	Percent Survival	Percent Females	Eggs/ Female/Month
Eggs	300	1 mo.	50		
Larvae	200	1 mo.	50		
Adults	100		50 per mo.	50	10

To illustrate the effects of stressors on populations, we will use a very simple simulation model. We'll call our organism *Hypothetical what-if*, or the What-If Bug.

The What-If Bug has three stages: an egg, a larva, and an adult. The eggs and larva each take one month to complete their development, and 50 percent survive to the next developmental stage (egg to larva, larva to adult). Adult survival is 50 percent per month. In other words, of the original 100 adults in our example, 50 will be alive at the end of 1 month, 25 at the end of 2 months, and so on. One lucky individual will live to the ripe old age of 7 months. The What-If Bug has a sex ratio of 0.5; that is, 50 percent of the adult population is female. Every month, each female lays 10 eggs.

Our simulations start out with 300 eggs, 200 larvae, and 100 adults. We then run the simulation for 25 "months," first with the parameters shown here, then changing one parameter to see the effect of reduced survival of a life stage, reduced egg production, or changes in the sex ratio. The next four figures show the effects of hypothetical stressors on our hypothetical population.

- In the first figure, we reduce egg survival from 50 percent to 45, 40, and 35 percent.
- In the second figure, we reduce adult survival in the same manner.
- In the third figure, we reduce eggs per female from 10 to 9.7 and 5 eggs per female.
- In the fourth figure, we vary two parameters simultaneously. Both adult survival and the percent of the population that is female are reduced from 50 percent to 45, 40, and 35 percent.

Let's look at the results. You will note that the top curve in each graph represents the initial conditions that we presented earlier. All the curves represent the total population (eggs, larvae, and adults) over the 25- month period.

Optional Exercise (Continued)

Egg Survival

Assume that the What-If Bug lays its eggs in soil contaminated with a chemical that is slightly toxic. Suppose that the toxic effects of the contaminant only reduce egg survival from its normal 50 percent to 45 percent. The graph in Figure 1 shows that the population at the end of 25 months is about half what it would be with no additional egg mortality, down from about 2400 to about 1200. If the contaminant causes egg survival to decrease to 40 percent, the population does not grow at all, and if egg survival drops to 35 percent, the population declines.

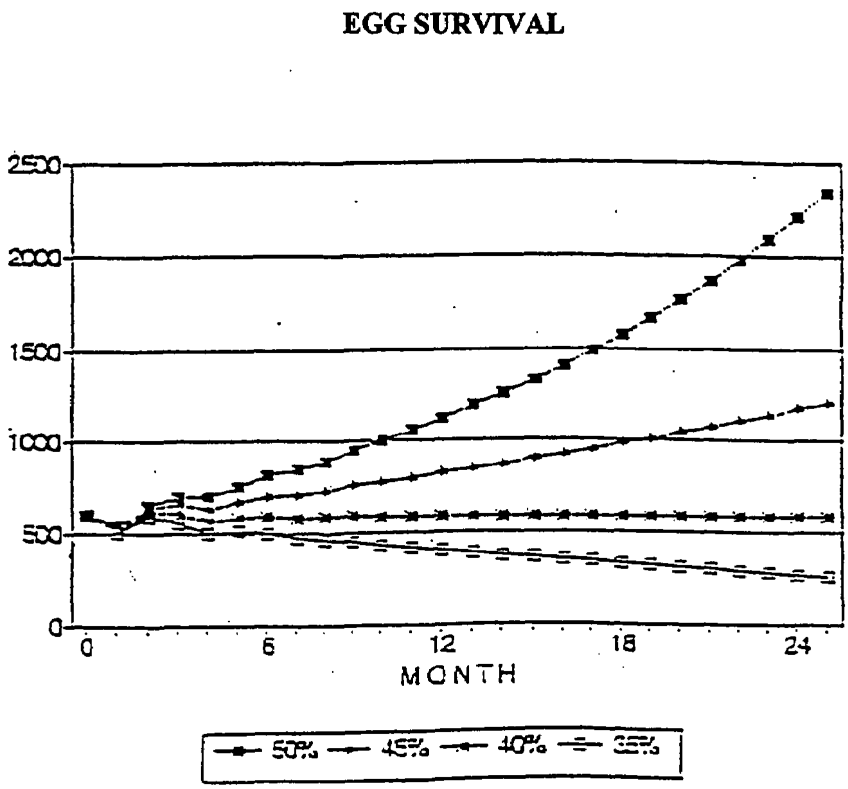


Figure 1. Number of eggs of What-If Bug surviving over 25 months

Optional Exercise (Continued)

Adult Survival

The adult What-If Bug feeds on flowers that grow along pesticide-treated vegetable fields. Drift from the pesticide spraying lands on the flowers, killing some What-If Bugs (Figure 2).

- The population fails to grow at all when adult survival declines just to 45 percent.
- Reductions in survival to 40 and 35 percent result in significant decline in the population.

ADULT SURVIVAL

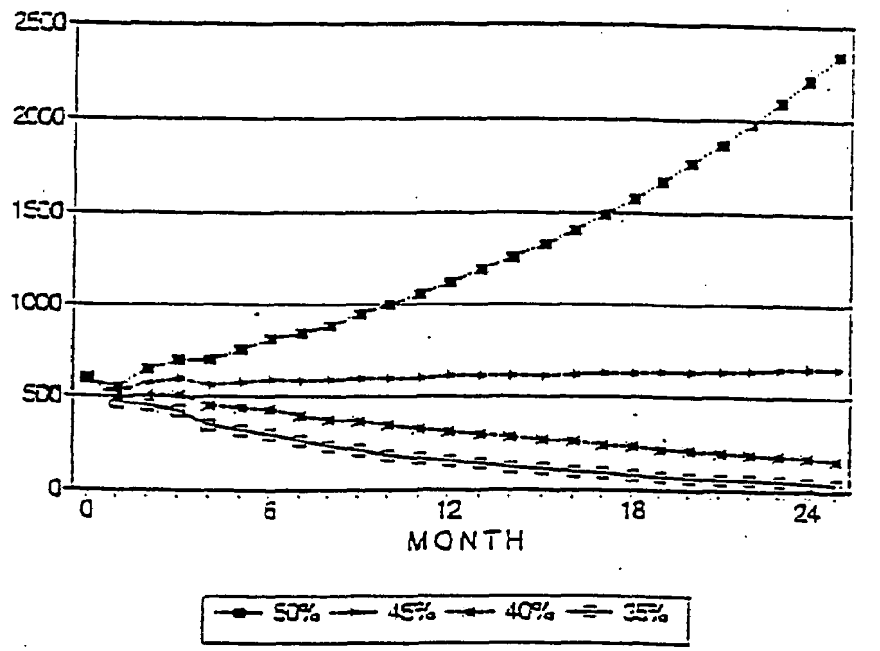


Figure 2. Number of adult What-If Bugs surviving over 25 months

Optional Exercise (Continued)

Eggs per Female

Along the roadway, another flower serves as a food source for adult What-If bugs. The soil is so compacted at this site that the plants provide less nutrition and the female bugs produce fewer eggs.

- Figure 3 shows that a reduction to nine eggs per female causes the population to grow at about half the rate if egg production remains at 10 per female.

- At five eggs per female, the population is heading for extinction.

EGGS PER FEMALE

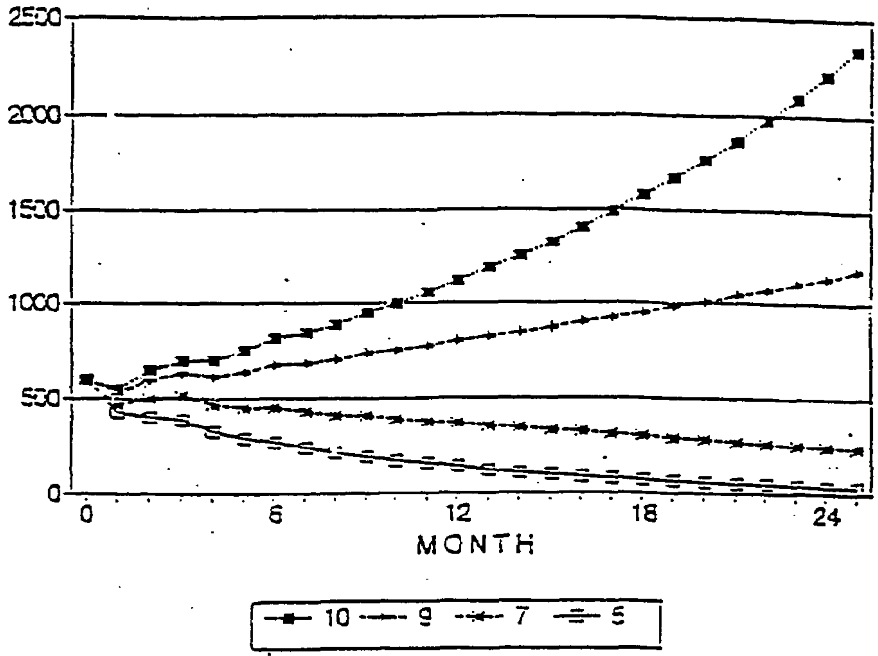


Figure 3. Number of eggs per female What-If Bug over 25 months

Optional Exercise (Continued)

Adult Survival and Percent Females

The What-If bug survives best in partially shaded environments where the temperature is moderate in summer. Females are more susceptible than males to high temperatures, but both suffer some additional mortality. In Figure 4 both adult survival and the percent of the population that is female were reduced. To keep things simple, we used the same numbers for each: 50, 45, 40, and 35 percent.

- As seen in Figure 4, with just a 5 percentage point decline in the two parameters, the population declines. At 40 and 35 percent, the population is quickly becoming extinct.

ADULT SURVIVAL/% FEMALE

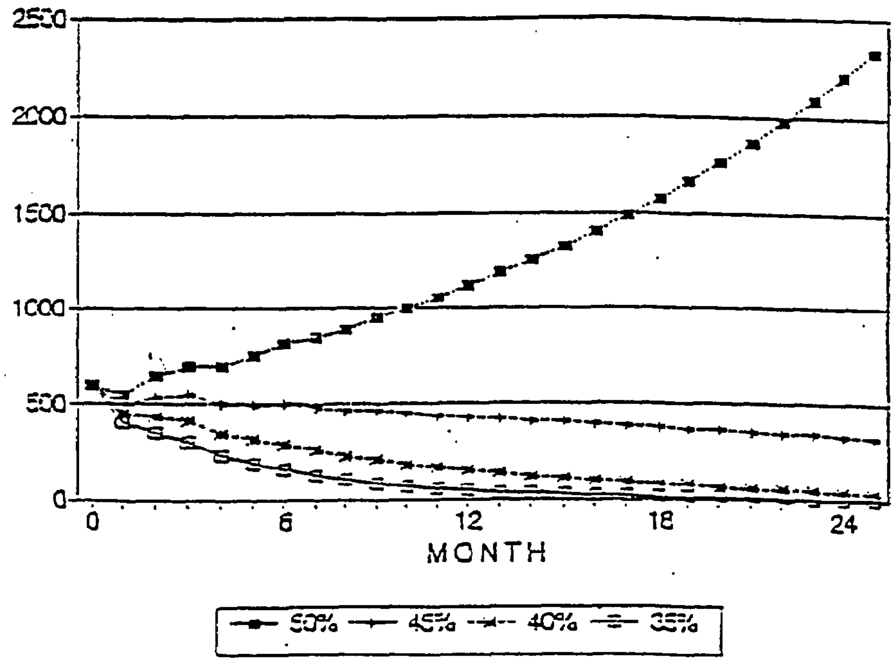


Figure 4. Survival of adult What-If Bugs when percent females change over 25 months

Optional Exercise (Continued)

The figures show that small differences in survival, reproductive rates, and sex ratios can produce large differences in population size over the long term.

- You may have noticed that in some of the curves the population increased at first, then declined. How far into the future can/should we consider when looking at effects?
- In several instances, the population increased, but not as much as with the original parameters. Should a population actually decrease before the effects are considered significant? How much is too much?

3. Ecological Risk Mgmt. and Decision Making

3. ECOLOGICAL RISK MANAGEMENT AND DECISION MAKING UNIT

Contents

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Summary of Ecological Risk Management and Decision Making Unit

Time Allotted

Approximately 60 minutes allowed for discussion and lecture.

Summary of the Unit

The Ecological Risk Management and Decision Making Unit provides an overview of ecological concerns within Environmental Protection Agency (EPA) programs, the statutory basis of these concerns, examples of ecologically-based decisions, and other risk management factors. Also, recommendations to improve ecological risk management are provided.

Key Concepts

- A range of ecological concerns have been used as the basis for EPA regulatory and non-regulatory programs. EPA has generally based ecological decisions on acute mortality caused by chemical stressors in test animals, especially aquatic test species.

- Statutes which form the basis for most EPA ecological policy are the Clean Water Act, National Environmental Policy Act, and Endangered Species Act. Most ecologically-based decisions have been made in the Office of Water and Office of Federal Activities, with a few in other programs.

- Precedents for ecologically-based decisions exist for all EPA programs.

- Other risk management factors include economics, the political process, statutory and legal considerations, and public concerns.

- Many ecological values are hard to measure, and traditional economic methods for monetization are not applicable.

- In order to manage ecological risk better, the ecological risk assessment and decision making process must improve by developing tools such as training, guidance, and better ecological and economic methodologies, and by recruiting of staff with ecological expertise.

References

USEPA. 1995. *Ecological Risk: A Primer for Risk Managers.* U.S. Environmental Protection Agency. Prepared for The Agency Ecological Risk Management Communication Group by the Office of Prevention, Pesticides and Toxic Substances; Office of Water; Office of Policy, Planning and Evaluation; Office of Research and Development; and Office of Solid Waste and Emergency Response. Washington, DC.

USEPA. 1994. *Managing Ecological Risks at EPA: Issues and Recommendations for Progress.* U.S. EPA Office of Research and Development and Office of Policy, Planning and Evaluation. EPA/600/12-94/183. Washington, DC.

MANAGEMENT UNIT

Ecological Risk Management

and

Decision Making

This unit will cover the following topics:

- Ecological concerns that form the basis of EPA programs;
- The statutory basis for most of EPA's ecological policy;
- Examples of ecologically-based decisions in EPA program offices;
- Other risk management factors; and
- Recommendations to improve ecological risk management.

MANAGEMENT UNIT

Range of Ecological Concerns Used in EPA Programs

- Algae
- Aquatic communities
- Fish
- Habitats
- Mammals
- National forests
- Vegetation
- Water quality
- Wildlife

Source: Managing Ecological Risks at EPA: Issues and Recommendations for Progress (EPA, 1994a)

A survey was conducted of all EPA Headquarters program offices and four Regional offices (Regions 3, 5, 9, and 10). This survey documented historical and current ecological concerns on which those offices made decisions.

The survey report, *Managing Ecological Risks at EPA: Issues and Recommendations for Progress* (USEPA, 1994a), was compiled to assist in developing future guidance on risk management and ecological risk assessments, as well as to provide a set of recommendations to improve ecological considerations in EPA decision making. A copy of this report is in your course materials.

The survey revealed that a variety of ecological concerns have been used within the Agency either partially or completely as the basis of regulatory decisions or decisions to pursue some other programmatic objective or activity, such as a cooperative non-regulatory effort to protect or reduce risks to a particular species or ecosystem (USEPA, 1994a).

Examples of ecological concerns used in various EPA programs include: algae, fish, mammals, vegetation, and water quality. Several concerns have direct benefit to humans, such as commercial fisheries and wetlands. Others have statutory authorities that justify their protection (e.g., listed species, biological integrity). Pages 10 and 11 and Appendix D of the report contain additional information on concerns used in past EPA actions. In summary, EPA has generally based ecological decisions on acute mortality caused by chemical stressors in test animals, especially aquatic test species.

MANAGEMENT UNIT

Primary Ecological Statutes and Programs

- **Statutes from which most EPA ecological policy developed:**
  - **CWA**
  - **NEPA**
  - **ESA**
- **Most ecologically-based decisions found in the Office of Water and the Office of Federal Activities.**

Most of the ecological policy at EPA was developed by implementing the Clean Water Act (CWA), the National Environmental Policy Act (NEPA), and the Endangered Species Act (ESA). It is not surprising that most ecological decisions are made in the Office of Water and the Office of Federal Activities. However, ecologically-based decisions have been made in all the program offices and can serve as precedents for future decisions. Refer to Appendix F of the report, *Managing Ecological Risks at EPA: Issues and Recommendations for Progress* (USEPA, 1994a), for further information on these decisions.

MANAGEMENT UNIT

Examples of Ecologically-Based Decisions

- FIFRA: Diazinon Special Review
- Superfund: Commencement Bay, WA
- NEPA Review: Southeastern Expressway, VA
- CWA Section 404 Review: Ocean Development Company
- TSCA PMN: Neutral Organic Compound
- RCRA: Hamilton Standard, Windsor, CT
- CAA: Half Moon Power Plant, NY

Although most ecologically-based decisions have occurred in the Office of Water and the Office of Federal Activities, there are examples of decisions in other programs which demonstrate it can be done. More emphasis on ecological decisions in these programs is needed to provide a balance between ecological and human health concerns in Agency decisions. Provided below are examples of ecologically-based decisions representing all the programs.

FIFRA: Diazinon Special Review

EPA is responsible for regulating use of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). In 1985, the Office of Pesticide Programs reviewed the use of diazinon, a liquid/granular broad spectrum insecticide used in agriculture (40%), homes (20%), and golf courses and sod farms (40%). This was in response to reports of approximately 80 bird kills involving a few to a thousand individuals that were attributed to diazinon. The Special Review focused on golf courses and sod farms, since many of the bird kills were associated with grassy sites.

The ecological risk to grazing waterfowl and seed-eating birds known to forage on grassy sites was evaluated by examining acute toxicity studies; estimating residues on grass and seed, and dose levels consumed by birds (from grass and seed); and reviewing field studies, bird kills, and a local population reduction of Atlantic Brant Geese. The risk assessment found that:

- Estimated residue levels and consumption levels for grass and seed exceeded the LD_{50} level for mallard ducks;

Examples of Ecologically-Based Decisions (Continued)

- Granular diazinon was hazardous to birds at all labeled application rates, with ingestion of a few granules killing smaller birds;
- Carcass analyses of dead birds confirmed diazinon as the cause; and
- A significant reduction occurred in a local population of Atlantic Brant Geese.

Consultation with the U.S. Fish and Wildlife Service found that certain endangered and threatened species could be seriously affected by the use of diazinon on golf courses and sod farms. Results of the benefits assessment indicated that increased costs to golf course and sod farm industries associated with alternative pesticides would not be significant.

The decision was to restrict the use of diazinon on golf courses and sod farms because the ecological risks outweighed the benefits. This decision was challenged and the Administrative Law Court found that recurring bird kills were sufficient evidence of unreasonable adverse effects, and neither reductions in populations nor effects on endangered or threatened species were required evidence.

Superfund: Commencement Bay, WA

The Commencement Bay (Puget Sound, WA) Superfund site represents one of the increasing examples of a Superfund Remedial Investigation and Feasibility Study (RI/FS) based upon ecological concerns. In 1985, an ecological risk assessment was conducted to characterize the impacts on aquatic organisms of exposure to contaminated sediments. Measures of exposure and effects included sediment chemistry, sediment toxicity (bioassays), benthic (living on the bottom) macroinvertebrate abundances, concentrations of contaminants in English sole and crab, and prevalence of liver lesions in English sole. The risk assessment found that:

- Average concentrations of several organic compounds exceeded all Puget Sound reference conditions;
- Concentrations of selected metals, sediment toxicity bioassays, and chemicals indicative of bioaccumulation were significantly above reference stations;
- Benthic macroinvertebrate abundances were depressed at the Superfund site; and
- English sole liver lesions were statistically significant at most of the Superfund site sampling stations.

The RI/FS concluded that actual or threatened releases of hazardous substances from this site, if not corrected by response actions, present an imminent and substantial endangerment to public health, welfare, and the environment. In 1989, a Record of Decision was signed that presented remediation actions for the site.

Examples of Ecologically-Based Decisions (Continued)

NEPA Review: Southeastern Expressway, VA

EPA is responsible for reviewing environmental impacts of major Federal actions including proposed legislation, regulations, and major actions requiring Environmental Impact Statements (EISs) under the National Environmental Policy Act (NEPA). NEPA reviews are conducted by the Office of Federal Activities and the Regions. In 1990, Region 3 reviewed a Virginia Department of Transportation and Federal Highway Administration EIS for the Southeastern Expressway proposed for the Cities of Chesapeake and Virginia Beach, VA. Information and analysis of impacts from the proposed expressway and provisions for their avoidance or reduction were presented in the EIS. The EIS showed that all the alternatives (except no action) had adverse impacts and proposed mitigation of these impacts was minimal. The Region 3 review found that the Southeastern Expressway proposal was environmentally unsatisfactory due to potential impacts to wetlands (300-500 acres) and water supply, and secondary impacts such as promoting development in a sensitive area. This resulted in further negotiations over the route of the expressway.

CWA Section 404 Review: Ocean Development Company

EPA has responsibility for permit review and enforcement under Section 404 of the Clean Water Act (CWA) which pertains to discharges of dredged and fill material into aquatic ecosystems. The U.S. Army Corps of Engineers is responsible for granting CWA Section 404 permits and Section 10 (Rivers and Harbors Appropriation Act of 1899) permits for dredging in waters of the U.S. Region 9 reviewed a permit application by Ocean Development Corporation Company to build a luxury hotel in a wetland area in the Republic of Palau (former Trust Territory of the U.S. in the Western Pacific). Region 9 found that the proposed filling of 139 acres of mangrove swamps, agricultural wetlands, seagrass beds, and reef flats would likely cause significant adverse effects. The EPA worked with the developer to reduce the fill to the reefs and seagrasses. The decision by the Corps was to approve a scaled-down version of the project without mitigation.

TSCA PMN: Neutral Organic Compound

Section 5 of the Toxic Substances Control Act (TSCA) requires manufacturers and importers of new chemicals to submit a premanufacture notice (PMN) to EPA before they intend to begin manufacturing or importing. EPA determines whether the substance will present an unreasonable risk of injury to human health or the environment. The approach used in the ecological risk assessment is to compare estimated future exposure concentrations with ecological effect concentrations. Most assessments are paper exercises due to the 90-day requirement to make a decision on risk. The following example is an exception to that rule because the initial screening indicated risk.

The new chemical that was evaluated is known as a neutral organic compound (the chemical name is not known due to the confidential business information protection afforded by TSCA). Processing, use, and disposal sites for this chemical were proposed to be located adjacent to rivers and streams.

The ecological risk assessment examined risk to populations and communities of organisms living in the water column and on the bottom. Exposure analysis consisted of a tiered approach starting with the worst case scenario using simple stream flow dilution models and moving on to more sophisticated models. The exposure

Examples of Ecologically-Based Decisions (Continued)

model data and the effects analysis was comprised of a quantitative structure-activity relationship (an estimation of toxicity based upon the chemical characteristics of the compound) and tests of mortality, growth and development, and reproduction. Effects data indicated little risk to benthic organisms at the identified sites of product use and disposal. The final decision was to restrict use of the new chemical to the identified sites.

RCRA: Hamilton Standard, Windsor, CT

The Hamilton Standard corrective action facility represents one of the few examples of interim corrective measures based to a large degree on potential threats to ecological receptors. The Hamilton Standard facility is involved in the manufacture of aerospace products and is hydrogeologically upgradient of wetlands and a reservoir which is the site of a state salmon restoration project. A groundwater plume containing hexavalent chromium and halogenated solvents extends from the facility to the wetlands area. In 1993, EPA-New England, in lieu of Hamilton Standard, conducted chemical and toxicity analyses of wetland waters and sediments. Based on the demonstrated toxicity to laboratory organisms, the exceedence of state and Federal ambient water quality criteria, and the importance of the fisheries resource, EPA-New England concluded that the conditions may present an imminent and substantial endangerment under the Resource Conservation and Recovery Act (RCRA) Section 7003. Hamilton Standard agreed to enter a consent agreement under RCRA Section 3008(h) to undertake actions to mitigate plume impacts to the wetlands, including collection of contaminated waters at off-site seeps and a groundwater plume capture system at the facility boundary. The consent agreement also provides for long-term wetlands habitat monitoring to gauge any impacts from potential hydrologic alterations due to the groundwater capture system.

CAA: Half Moon Power Plant, NY

EPA has responsibility for issuing air permits in states without delegated authority. Under the Clean Air Act (CAA), ecological risk assessments are conducted by federal land managers for Class I areas (national parks, forests, etc.). EPA reviewed an air permit application for the proposed Half Moon Power Plant under the Prevention of Significant Deterioration (PSD) program, which is designed to ensure that geographical areas do not exceed the national air quality standards. The U.S. Forest Service evaluated the ecological risks associated with the proposed emissions and found that sulfuric acid deposition would compromise the buffering capacity of sensitive lakes in the Lye Brook Wilderness, VT, Class I area. The EPA eventually approved the permit after mediating a solution to the problem between the Forest Service and the applicant, which involved developing appropriate offsets for new sources of air pollution to prevent ecological impacts.

Non-Regulatory Ecologically-Based Decisions

- MOU Between EPA and The Nature Conservancy
- Great Lakes National Program Office Habitat Restoration Grants
- National Estuary Program

Examples of non-regulatory ecologically-based decisions include funding and working together with other organizations to address high priority ecological risk issues (e.g., habitat loss, biodiversity, eutrophication, toxic contamination, etc.).

MOU Between EPA and The Nature Conservancy

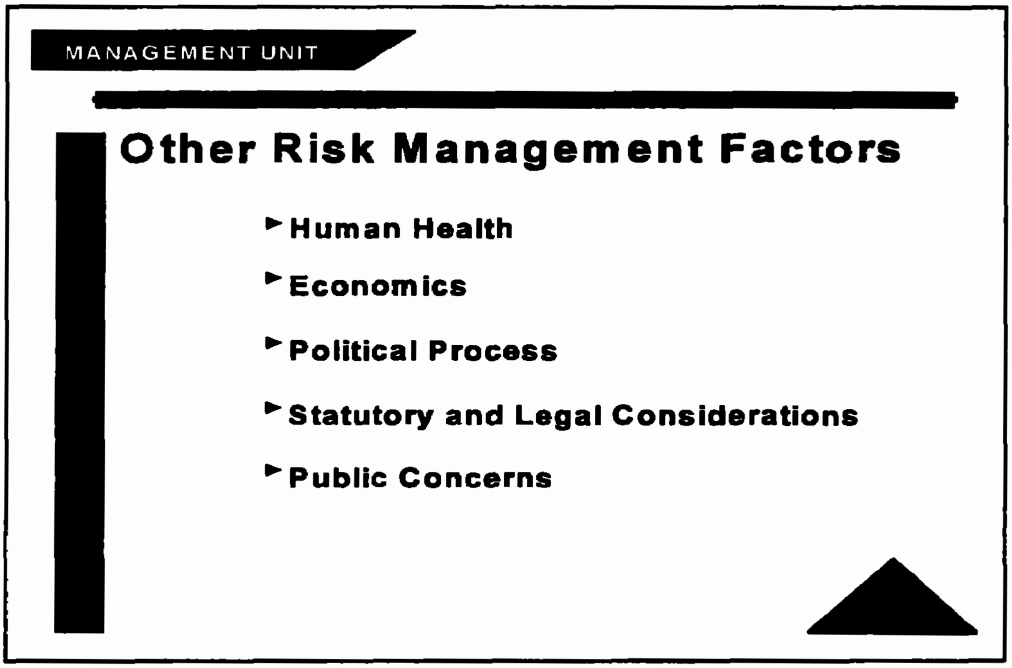
In 1992, the Office of Water signed an MOU with The Nature Conservancy to provide a framework for cooperation and coordination in a wide range of activities of mutual interest in the U.S. and internationally. These issues relate to protection of water quality and habitat; conservation of biodiversity, ecosystems, landscapes at the watershed level; and to the threatened, endangered, and sensitive plants and animals that they contain. The MOU led to cooperative efforts between TNC and other program offices and the regions, e.g., Clinch River (Virginia) sustainable development project, Mackinaw River (Illinois) watershed project, and Creating Sustainable Ecosystems, Economies, and Communities: Lessons Learned handbook project (OPPE).

Great Lakes National Program Office Habitat Restoration Grants

Restoration of the full functioning of the Great lakes ecosystem requires toxics reduction, restoration of habitat and control of exotic species. In achieving this goal, the EPA Great Lakes National Program Office established grants for habitat restoration which emphasize on-the-ground actions. Examples of projects include TNC synthesis of the state natural heritage data for the Great Lakes Basin, restoration of naturally reproducing lake trout population, and revegetation of slag with native species in NW Indiana.

National Estuary Program

The NEP provides grants to states, regional and interstate agencies, other public or non-profit private organizations and individuals to prepare Comprehensive Conservation and Management Plans (CCMPs) to ensure ecological integrity of nationally significant estuaries threatened by pollution, development, or overuse. A management conference of stakeholders in convened to characterize the estuary, define the estuary's problems, and then develop a CCMP. In addition to the grants, EPA provides technical assistance to the states throughout the process.



Some other general risk management concerns that factor into an ecological risk decision include:

- **Human Health:** Human health concerns sometimes factor into ecological risk decisions. For example, contamination of fish tissue may be of concern at an aquatic superfund site. When assessing a pesticide, alternative pesticides would be examined and human health effects of the pesticides might be compared as part of the analysis.

- **Economics:** Some statutes require consideration of benefit/cost and other economic effects of decision alternatives. Although tools are available to express the value of ecological resources monetarily, in most cases, the value must be expressed qualitatively. This will be discussed in more detail in the following slide.

- **Political Process:** Political issues may also become involved in ecological risk management decisions. This is evident when laws are amended, when Executive Orders are issued, or when regulations or new guidance are developed.

- **Statutory and Legal Considerations:** The implementation of a law takes into consideration the legislative history of the law, precedent both scientific as well as legal, compliance with any statutory deadlines, and compliance and enforcement associated with a regulatory action. This may sometimes require that decisions be made without the most thorough investigation of all issues, and that issues under consideration be prioritized. Regulatory action or remediation may be segmented to meet the greatest need, and other issues dealt with later. Finally, consideration should be given to the ability of the regulated parties to comply with the decision and the agency to enforce the decision.

Other Risk Management Factors (Continued)

- **Public Concerns:** The public may express its concerns regarding a pending ecological risk management decision in many ways. A national environmental group or trade association may send a letter or petition to EPA or elected representatives, or even file a lawsuit in some instances. Local citizen groups may participate in the regulatory processes or make their opinions known through the news media. For non-regulatory decisions (e.g, National Estuary Program), public concerns are heard through participation on committees and activities and through public meetings, computer bulletin boards, etc.

The following discussion will focus on economics, specifically how we value ecological resources.

MANAGEMENT UNIT

Valuing Ecological Resources

Value Easy to Measure, Monetize		**Value Difficult to Measure, Monetize**
Commercial Fisheries, Timber	Recreational Fishing, Birdwatching, Hiking	<u>Ecosystem Functions & Services</u> Habitat Biodiversity Oxygen Production Nutrient Cycling Flood Control <u>Cultural</u> Spintual Religious Ethics

The following discussion will focus on economics, specifically, how we value ecological resources.

Ecological values that are easy to measure and monetize tend to be those that derive from human use, e.g., commercial fishing and timber harvesting. Some human uses (birdwatching, recreational fishing) may be more difficult to measure and monetize as they are not directly traded in markets.

Many ecological values (habitat, biodiversity, oxygen production, etc.) are hard to measure and traditional economic methods for monetization are not applicable. Therefore, these life support values or ecosystem functions and services must be expressed in qualitative terms.

Other concerns related to valuing ecological resources include spiritual, religious, and ethical concerns. Different cultures may value ecological resources differently. For example, the Native Americans of the Pacific Northwest Tribes impart a cultural and religious significance to the migratory salmon of the Columbia River Basin. These tribes place a level of importance to the salmon's survival beyond the commercial and aesthetic values that most people living in the region ascribe to these resources. Finally, the value of ecological resources to future generations is an ethical consideration.

Consideration must be given to short- and long-term effects of stressors on these values and whether effects are reversible or irreversible. Given the uncertainty in characterizing ecological values, it may be prudent to err on the side of precaution.

MANAGEMENT UNIT

Recommendations to Improve Ecological Risk Management

1. Ensure an appropriate balance between ecological, human welfare and human health concerns in EPA regulations and policies.

2. Develop common Agency-wide ecological protection concerns.

3. Encourage an open process for developing ecological concerns and assessment endpoints.

4. Specify rationale and establish precedents for ecological protection.

Managing Ecological Risks at EPA: Issues and Recommendations for Progress (USEPA, 1994a)

The first four of eight recommendations listed in the report, *Managing Ecological Risks at EPA: Issues and Recommendations for Progress* (USEPA, 1994a), focus on changing Agency policy and attitudes toward ecological concerns.

Although protection of human health is still emphasized at the Agency, **many current activities offer opportunities to examine ecological** and human welfare with respect to natural resource concerns (e.g., regulating pollution and dredge-and-fill operations). Another opportunity to balance human health with ecological concerns is the Agency's new Tiering Process for Regulatory and Policy Development, where priorities for regulation, policy development, and cross-media interaction are determined.

Agency-wide principles or objectives can be developed to establish an initial, overall **set of ecological concerns** for use in developing regulations and policies, and for ecological risk assessments. The public, natural resource trustees, and other **stakeholders should be consulted** to help identify concerns and establish goals for environmental protection. This open process will assist in promoting cross-media efforts within EPA and enhance public support for reducing ecological risks.

Ecological decisions and their rationales should be documented. Such decisions, particularly those based on strong scientific and societal justification, could then be used as precedents for similar future decisions. However the report noted that the development of new approaches to making better ecological decisions should not be constrained by such precedents.

MANAGEMENT UNIT

Recommendations (Continued)

5. **Set up formal processes to ensure effective interaction between risk managers and assessors.**
6. **Develop ecological risk management guidance and training, and recruit additional staff with ecological expertise.**
7. **Improve ecological risk communication.**
8. **Explore, develop, and apply new scientific tools for ecological risk assessment, and economic tools for ecological risk management.**

The other recommendations include changes in procedures to improve the ecological risk assessment and decision making process.

Although the *Framework for Ecological Risk Assessment* (USEPA, 1992) stressed that **interactions between ecological risk assessors and managers were critical**, the report suggested that formal processes could be established to ensure this occurs, **particularly during the scoping, problem formulation phase of the assessment**.

Additional guidance and training in management and communication of ecological risks were also identified in the report as critical to support the policy changes within the Agency. The **recruitment of more experts in ecology**, biology, and ecotoxicology should strengthen EPA's ability to develop ecological risk assessments, which will improve credibility.

> *Agency guidance on ecological risk management entitled, Ecological Risk: A Primer for Risk Managers (USEPA, 1995), was recently developed by the Agency's Ecological Risk Management Communication Group. This group is comprised of Division Directors and Deputy Office Directors from the Agency's ecological offices. Its goal is to establish ecological protection as a principal objective in Agency risk management decisions and implementation strategies. (A copy of the Primer is in the Appendix of the Participant's Manual.)*

The report also suggested that the continued success of EPA's evolving emphasis on ecological concerns will depend on the development of new scientific and economic tools to collect and analyze ecological data and predict ecological risks.

MANAGEMENT UNIT

Key Concepts

- A range of ecological concerns have been used as the basis for EPA regulatory and non-regulatory programs. EPA has generally based ecological decisions on acute mortality caused by chemical stressors in test animals, especially aquatic test species.

MANAGEMENT UNIT

Key Concepts (Continued)

- Statutes which form the basis for most EPA ecological policy are the Clean Water Act, the National Environmental Policy Act, and the Endangered Species Act. Most ecologically-based decisions have been made in the Office of Water and the Office of Federal Activities, with a few in other programs.

- Precedents for ecologically-based decisions exist for all EPA programs.

MANAGEMENT UNIT

Key Concepts (Continued)

- **Other risk management factors include economics, the political process, statutory and legal considerations, and public concerns.**
- **Many ecological values are hard to measure, and traditional economic methods for monetization are not applicable.**

MANAGEMENT UNIT

Key Concepts (Continued)

- **In order to manage ecological risk better, the ecological risk assessment and decision making process must improve by developing tools such as training, guidance, and better ecological and economic methodologies, and by recruiting staff with ecological expertise.**

4. Ecological Risk Assessment

4. ECOLOGICAL RISK ASSESSMENT UNIT

Contents

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Summary of Ecological Risk Assessment Unit

Time Allotted

Approximately 45 minutes for lecture and discussion.

Summary of the Unit

This unit presents the different kinds of ecological risk assessments conducted inside and outside the EPA.

Key Concepts

- The Agency conducts or reviews a variety of ecological risk assessments.
- There are other types of ecological assessments.
- In assessments, one size does not fit all.

References

Stephan, C.E. 1985. *Are the Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life and its Uses Based on Sound Judgments?* In: Cardwell, R.D., R. Purdy, and R.C. Bahner, eds. Aquatic Toxicology and Hazard Assessment: Seventh Symposium. ASTM STP 854. Philadelphia, PA: ASTM. pp.515-526.

U.S. EPA. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers, Benthic Macroinvertebrates and Fish.* Office of Water (4503F). EPA/444/4-89/001.

U.S. EPA. 1985. *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses.* NTIS No. PB85-227049. Duluth, MN: Environmental Research Laboratory.

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Ecological Risk Assessment

It is important that we first understand what an ecological risk assessment is, and that there are a variety of types of ecological risk assessments in addition to those employing the "Framework for Ecological Risk Assessment." Though this course will not go into the details of how various assessments are used, it is important to know that there are many types of risk assessment methods, and that each is tailored for specific purposes.

This unit will cover the following topics:

- Various types of ecological risk assessments and tools; and
- A classification scheme for these assessments and tools.

Examples of EPA Ecological Risk-Related Tools

- Aquatic Life Water Quality Criteria, Sediment Quality Criteria, Wildlife Criteria
- Wastewater and Ambient Toxicity Testing
- Quotient Method (Pesticides, Toxics, Superfund, RCRA)
- Rapid Bioassessment Protocols
- Vegetation Surveys, Earthworm Toxicity, Food Chain Modeling, Bioaccumulation Tests

Examples of Ecological Risk-Related Tools

Ecological risk tools are used in ecological risk assessments to analyze impacts to ecological components. Some examples include the following:

- **Aquatic Life Water Quality Criteria** are chemical-specific national tools designed to protect aquatic organisms from chemicals in surface water. Risk to aquatic organisms is assessed by examining acute and chronic toxicity to a minimum of eight taxonomic groups of fish and aquatic invertebrates and one or two plant species. The criterion is set to be protective of 95 percent of species in an aquatic community. It is assumed that aquatic community structure and function will be preserved if 95 percent of the species are protected and if a broad range of taxonomic groups are represented. National Ambient Water Quality Criteria have been established for many of the CWA priority pollutants including almost all metals and many of the important pesticides.

- **Sediment Quality Criteria (SQC)** predict concentrations of individual chemicals present in sediments that are protective of benthic organisms (i.e., those living on or in the sediments on the bottom of the water body). Toxic contaminants in sediments have the potential for adverse ecological effects even when the overlying waters are in compliance with water quality criteria. The Agency developed a draft proposal of SQC for five priority pollutant chemicals.

- **Wastewater and Ambient Toxicity Testing** is aimed at detecting additive, synergistic, or antagonistic effects in mixtures of pollutants. To supplement chemical-by-chemical analysis, EPA and many state water programs require some form of toxicity testing, in which test organisms, usually fish and/or aquatic invertebrates, are exposed to various dilutions of effluent or ambient water. If toxicity is detected, follow-up studies may be undertaken in an attempt to determine which fraction of the pollutant matrix, or even which particular pollutants, are the key sources of toxicity.

Examples of Ecological Risk-Related Tools (Continued)

- **Wildlife Criteria** estimate concentrations of individual pollutants in the water column that should not result in buildup through the aquatic food chain to levels that would cause mortality, or developmental or reproductive impacts to mammals or birds whose diets are comprised largely of fish and other aquatic life. EPA has recently issued its first set of ambient water quality criteria aimed at protecting mammals and birds (otters, eagles, etc.) in the Great Lakes from the effects of consuming fish contaminated with highly bioaccumulative pollutants, including mercury. For each taxonomic class, key data used in calculating these criteria are exposure information for selected species representative of those most likely to be exposed to bioaccumulative contaminants through the aquatic food web and a NOAEL (No Observed Adverse Effect Level) or LOAEL (Lowest Observed Adverse Effect Level) from a study assessing the effects of a given contaminant on an acceptable endpoint.

- The **Quotient Method** calculates a numerical estimate of the likelihood that an ecotoxicological effect of concern might occur by dividing the estimated environmental concentration by the toxicological level of concern. This method is used in screening chemicals and risk assessments in the Superfund, RCRA, Pesticides, and Toxics programs.

- **Rapid Bioassessment Protocols** evaluate community-level effects of various water quality impairments (e.g., toxic loadings from groundwater recharge, industrial effluents, surface water runoff, physical alterations to habitat, and introductions of exotic species). The protocols can be used to:

  - Determine if a stream is supporting or not supporting a designated aquatic life use;
  - Characterize the severity of use impairment;
  - Help identify sources and causes of use impairment;
  - Evaluate effectiveness of control actions; and
  - Characterize regional biotic components.

  The analysis consists of comparing habitat (physical structure, flow regime) and biological measures (e.g., abundance of macroinvertebrates, fish assemblages) of a site to reference conditions. Once the relationship between habitat and biological potential of a reference site is understood, water quality, physical alteration, and exotic species impacts can be ascertained. Protocols have been developed for fish and benthic macroinvertebrates in certain types of aquatic environments.

  - **Terrestrial Ecology Tools** include qualitative and quantitative vegetation surveys, earthworm toxicity (Superfund site assessments), food chain modeling, and bioaccumulation tests.

Examples of EPA Ecological
Risk Assessments

- Superfund Ecological Risk Assessments
- Ecological Risk Assessment for Watersheds
- Global Climate Change Assessments
- Environmental Futures Project

Examples of EPA Ecological Risk Assessments

- **Superfund Ecological Risk Assessments** estimate the likelihood that adverse effects will or have occurred as a result of exposure following release of hazardous substances. Proposed guidelines for these ERAs were developed based on the *Framework for Ecological Risk Assessment.*

- **Ecological Risk Assessment for Watersheds: Developing Guidance and Methods for Implementation.** The Office of Water Office of Science and Technology (OST) is developing guidance to evaluate risk at an ecosystem level that is derived from the *Framework for Ecological Risk Assessment* methodology and expanded through its application in watershed ecosystems. Regulatory programs alone cannot achieve the goal of ecosystem protection. A combination of targeted regulatory programs that are well integrated with non-regulatory and voluntary programs are most likely to achieve success. To make this effort work, an understanding of the adverse effects of particular stressors, and the combined effect of multiple stressors is essential if the best combination of management options is to be generated and resources targeted within a watershed. OST is developing a watershed risk assessment process that evaluates risk hypotheses about why observed changes in valued resources have occurred, and predicts what changes are likely to occur from future human impacts and management efforts. By identifying likely causes of ecological degradation, ecological risk assessment provides a scientific basis for targeting regulatory efforts, voluntary work, and limited resources toward management that controls those causes most likely to impair valued resources. Five case studies are being developed to support the technical guidance for watershed ecological risk assessment: Big Darby Creek (OH), Clinch River (VA), Middle Platte River Wetlands (NE), Snake River (ID), and Waquoit Bay Estuary (MA).

Examples of EPA Ecological Risk Assessments (Continued)

- **Global Climate Change Assessments** predict the effects of increased carbon dioxide, methane, and nitrous oxide (greenhouse gases) in the atmosphere, on the climate, and the resulting climatic effects on ecosystems. The assessments have included effects on coastal and marine resources (e.g., seagrasses, corals, marshes, and mangroves) and forests.

- **Environmental Futures Project. (Science Advisory Board Report).** The Ecological Processes and Effects Committee (EPEC) of the Science Advisory Board examined the ecological consequences of energy development and consumption in the United States as its contribution to the EPA Environmental Futures Project. One of EPEC's conclusions in its report, **"Futures Methods and Issues," A Technical Annex to *Beyond the Horizon: Protecting the Future with Foresight***, was that the Agency should consider using the *Framework for Ecological Risk Assessment* for assessing future environmental problems. This formalized approach (the Framework) revealed possible ecological consequences that otherwise probably would not have been determined.

Examples of Ecological Risk Assessments Conducted Outside EPA

- **State Natural Heritage Programs**
- **Environmental Impact Statements**
- **USFWS Habitat Evaluation Procedure (HEP)**
- **Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation**
- **Forest Ecosystem Management: An Ecological, Economic and Social Assessment**

Other Types of Ecological Risk Assessments

State Natural Heritage Programs

These programs are established under cooperative agreements with the Nature Conservancy (a private, non-profit organization dedicated to the preservation of natural diversity). They identify the state's most significant natural areas through inventories of natural heritage resources, such as rare plants and animals, geological landmarks, natural communities, and other natural features. These areas are ranked by considering the following:

- Global abundance - A = < 1,000 individuals; < 2,000 acres; <10 miles of stream
  D = > 10,000 individuals; > 50,000 acres; > 250 miles of stream;
- Global range - A = Narrow endemic (< 100 sq. mi.)
  D = Widespread (> 1,000,000 sq. mi.);
- Global trends - A = Declining rapidly
  D = Increasing;
- Proportion of habitats/populations that are protected -
  A = None protected
  D = Many protected;

Other Types of Ecological Risk Assessments (Continued)

- Degree of threat - A = Very threatened range-wide; species or community directly exploited or threatened by natural or man-made forces.
  D = Unthreatened on a range-wide basis; may be threatened in minor portions of range;

- Fragility (how susceptible an element is to degradation from external forces, such as pollution or climate change) - A = Extremely fragile
  D = Tough; and

- Other considerations (e.g., unexplained population fluctuations).

The state sets priorities for conservation based on anthropogenic threats. Conservation tools include land acquisition, conservation easements, and private landowner voluntary protection programs. This approach starts with the ecological resources and works back to the sources of stress.

- **Environmental Impact Statements** (EISs) predict the environmental impact of the proposed action and alternatives. The National Environmental Policy Act (NEPA) requires Federal agencies to prepare EISs for all major Federal actions significantly affecting the environment. The probability of both adverse and beneficial impacts is assessed.

U.S. Fish and Wildlife Service (FWS) Habitat Evaluation Procedure (HEP)

HEP assesses the quality and quantity of available habitat for selected wildlife species. It also provides for two different types of wildlife habitat comparisons for use in assessing the impact of a proposed activity:

- The relative value of different areas at the same point in time; and

- The relative value of the same area at points in the future.

Other Types of Ecological Risk Assessments (Continued)

Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation (U.S. Department of Interior National Biological Service)

This assessment estimated the declines of natural ecosystems in the United States through a literature review and survey of conservation agencies and professionals. The assessment found significant losses of biodiversity at the ecosystem level. Specifically, more than 30 ecosystems were critically endangered (greater than 98% decline); 58 ecosystems were endangered (85-98% decline); and more than 38 ecosystems were threatened (70-84% decline). Of the critically endangered ecosystems, the greatest losses were among grassland, savanna, and barrens communities. The most pronounced losses were found in the South, Northeast, Midwest, and in California. A recommendation resulting from this assessment was that integrated conservation plans for all ecosystems be developed in each ecoregion of the United States starting with the types and regions that have sustained the greatest loss and are at risk of further loss.

Forest Ecosystem Management: An Ecological, Economic, and Social Assessment (Forest Ecosystem Management Assessment Team)

The assessment is one of the results of the Forest Conference convened in Portland, Oregon, in 1993 to address the spotted owl issue. The assessment comprises an ecosystem approach to forest management addressing:

- Maintenance and restoration of biological diversity, particularly that of the late-successional and old growth forest ecosystems and current and predicted condition of the owl population under different management scenarios;
- Maintenance of long-term site productivity of forest ecosystems;
- Maintenance of sustainable levels of renewable resources, including timber, various forest products, and other facets of forest values; and
- Maintenance of rural economies.

Various management options will result from the assessment and be implemented through adaptive management.

Classification of Ecological Risk-Related Tools and Assessments

- **Local to Global**
- **Retrospective to Prospective**
- **Chemical-Specific to Multi-Stressor**

Classification of Ecological Tools and Assessments

Ecological risk assessments range from local to global, retrospective to prospective, and chemical-specific to multi-stressor.

Local to Global

Local: Superfund Site
Regional: Environmental Monitoring and Assessment Program (EMAP)
National: Aquatic Life Water Quality Criteria (ALWQC)
Global: Global Climate Change Assessments

Retrospective to Prospective

Retrospective: Rapid Bioassessment Protocols, EMAP
Prospective: EISs, Sediment Quality Criteria, ALWQC

Chemical-Specific to Multi-Stressor

Chemical-Specific: ALWQC, Quotient Method
Multi-Stressor: EMAP, Superfund

Key Concepts

- EPA conducts or reviews a variety of ecological risk assessments
- There are many other types of ecological risk assessments
- In assessments - one size does not fit all

5. COMMUNICATING WITH THE PUBLIC ON ECOLOGICAL ISSUES

Contents

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Summary of Communication Unit

Time Allotted

Approximately 60 minutes allowed for discussion and lecture.

Summary of the Unit

This unit provides an understanding of the value of dialogue with the public and the differences between communicating about human health and ecological risks.

Key Concepts

- Communicating with the public occurs throughout the process ranging from informal to formal communication.
- The Agency has significant experience communicating human health risk to the public, and less experience in communicating ecological risk.
- The major differences between communicating about human health and ecological issues relate to values, ecoliteracy, and technical issues.
- There is a need to generate more knowledge and interest about ecological issues through education and public outreach programs.
- It is important to involve the public and other stakeholders in the process. The public is often an important source of information.
- It is helpful to relate ecological resources at risk to human benefits.
- A variety of resources are available to form an expert team to assist in ecological risk communication.

References

Dover, M.J., E. McNamara, R. Krueger. 1995. *Communication with the Public on Ecological Issues: Insights from Related Literature.* Report under EPA Cooperative Agreement No. CX 823519-01-0.

Dover, M.J., and D. Golding. 1995. *Communicating with the Public on Ecological Issues: Workshop Report.* Report under EPA Cooperative Agreement No. CX 823519-01-0.

Golding, D., M.J. Dover. 1995. *Communicating with the Public on Ecological Issues: A Survey of EPA Staff.* Report under EPA Cooperative Agreement No. CX 823519-01-0.

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COMMUNICATING WITH THE PUBLIC ON ECOLOGICAL ISSUES

An important element in the ecological risk assessment and decision making process is effective communication with the public. Public involvement is usually required under environmental statutes. The public can often prove to be a valuable source of information on ecosystems such as population changes (e.g., birds) or other visible characteristics which have changed. This information can assist the Agency in defining risk assessment goals and focusing the best use of time and resources. Through early and ongoing dialogue with the public one can learn the concerns they have, their priorities and values, and consider that information in planning so final decisions address concerns of all stakeholders.

This unit will cover the following topics:

- EPA's experience with communicating human health risk;
- Differences in communicating ecological and human health risk to the public;
- Ecological risk communication examples: What can we learn?;
- Recommendations on how to better communicate ecological issues; and
- Resources available to communicate ecological risk to the public.

HUMAN HEALTH RISK COMMUNICATION

- Body of Knowledge
- Tools
- Training

Significant experience communicating human health risk to the public has led the EPA and others to develop a large body of knowledge in the risk communication field. This experience and research has produced an understanding of the factors that cause fear and outrage about human health risks. We have become familiar with the seven cardinal rules of risk communication, such as listening with respect to the public's concerns. We also have learned how important it is that the communication be multi-way, and that you know your audience as well as your own strengths and biases. We have also developed experience with many different communication tools (e.g., public meetings, community workshops, newsletters, television, public service announcements, etc.). These concepts, tools, and lessons learned should be applied to ecological risk communication.

To supplement this experience and research, the EPA has developed communication training courses. For training on communication techniques, EPA sponsors a **Risk Communication and Public Involvement** training course which covers general risk communication tools and practices. During this session, however, we will focus on the differences in communicating human health and ecological risks and concerns, and review some examples to learn how to better communicate ecological issues.

DIFFERENCES IN COMMUNICATING WITH THE PUBLIC:

Human Health vs. Ecological Issues

Values

A major difference between human health and ecological concerns is values. There is general consensus that the public values its health. However, there is less of a consensus among the public about ecological values and what to protect. Opinions range from protecting ecosystems because of their intrinsic value on one hand, to the view that ecosystems exist to provide resources to humans.

When communicating with the public, often it is helpful to relate ecological resources at risk to a range of human values, such as human health, economic development, aesthetics, future unknown uses or benefits to humans (such as cancer cures) morals, ethics, religion, and quality of life. However, it is also important to point out that there has been public agreement on certain ecological values to be protected, which have resulted in laws such as the Clean Water Act, the Marine Mammal Protection Act, the Migratory Bird Treaty, and the Endangered Species Act.

Ecological Literacy

Another reason why communicating with the public on ecological issues differs from human health concerns is that the public may not be as familiar with or aware of ecological issues. The public is likely to have received more information and be better educated on human health issues.

Technical Issues

These issues relate to ecological significance or the types and extent of anticipated effects. Ecological significance pertains to the nature and magnitude of effects, spatial and temporal patterns of effects, and recovery potential. The nature of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area are assessed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Differences in Communicating with the Public (Continued)

Magnitude of effects will depend on the ecological context. For example, a reduction in reproductive capability of a population would have greater effects on a whale population than on plankton (microscopic organisms living in the ocean) because whales take much longer to mature and produce fewer young over longer periods of time.

Spatial and temporal patterns of effects consider whether effects occur on large scales, (e.g., acid rain), or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves, (e.g., ozone depletion effects on marine ecosystems).

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

In conclusion, due to differing values, different levels of ecoliteracy, and various technical issues, there is a need for doing a better job in promoting the message of protecting our environment, and to educate children and the public.

Communicating Ecological Risk

Example: Superfund Cleanup

A Superfund cleanup was proposed for a man-made canal and wetlands in a state known for its concern for the environment and wildlife. The wetlands and canal feed into a naturally-occurring lake which is used for a great variety of industries and for recreation. The canal and wetlands are within the city while the lake is on the outskirts. The human health risks were borderline, not unacceptable. A cleanup was proposed in which half of the costs were to contain the groundwater contamination, thereby reducing the human health risk well below any level of concern. The other half of the costs were to protect the aquatic animals associated with the wetlands, which are at a significant risk. (Frogs and worms were used as indicators of the ecological risks of the area.)

The public response was overwhelmingly against the cleanup because it was perceived that so many dollars were being spent on frogs and worms. The public stated that if one could show how the canal and wetlands were affecting the fisheries in the lake, or other use the lake was providing, then they would be supportive.

Communicating Ecological Risk

Example: Spotted Owl in the Northwest

The spotted owl controversy in the northwestern United States is an issue which began as jobs versus owls, or protection of endangered species.

The Forest Conference, held in 1993, brought stakeholders together, with the result that they shared information each had about the ecological changes which may or may not impact the spotted owl. It was then discovered that those same changes were presenting a significant impact on other species, especially salmon. Once it was known that the salmon, a species of cultural and economic importance, was severely threatened, they realized that something had to be done on forest management in the region, river flow obstructions, etc. Points or values the stakeholders shared included:

- Familiarity of species;
- Cultural significance;
- Economic importance;
- Visible benefits;
- Controls which could be exerted, corporate or individual; and
- Benefits or losses to many parties, and not just a few (loss equally applicable to all parties).

Recommendations on How to Better Communicate Ecological Issues

Recently, a study of communicating with the public on ecological issues was completed by Clark University's Center for Technology, Environment, and Development under a cooperative agreement with EPA's Office of Policy, Planning, and Evaluation. The study included a literature review, survey of EPA personnel, and expert workshop (see Appendix C for workshop report and literature survey). Several recommendations for improving communication with the public resulted from this study.

Recommendations include:

- Avoid using poorly defined terminology (e.g., risk, ecosystem health or integrity) and jargon. Develop a common language accommodating scientific knowledge, lay understanding, and values.

- Do not automatically label an ecological issue as a problem.

- Since health issues are often of more concern to the public, it is helpful to draw the connection between ecological 'health' and human health to generate public interest and concern.

- Communicate local implications of ecological issues. Focus on particular places where possible, both to help publics personalize the issue and to convey the "systems" aspects of ecology.

- Frame discussions as much as possible in terms of the natural history of specific ecological components, rather than general principles or theories.

- Identify familiar themes that members of the public and scientists can relate to even though they stem from different conceptual frameworks (e.g., *preservation* of land for future generations and *preservation* of habitat).

- Because issues of concern and values differ among groups, tailor communication efforts (both content and approach) to meet the needs and concerns of different groups.

Available Resources to Better Communicate Ecological Issues

- **Communications Training**
- **Wildlife and Conservation Groups**
- **Agency Outreach Offices**
- **Case Studies**

What resources are available to communicate ecological issues and risks?

There are many resources to assist in effectively communicating ecological risk to the public. Information, guidance, and training can be provided from various sources, including EPA Headquarters and Regions, and academic institutions. Valuable information can be obtained from citizen groups and private parties. Lessons can be learned from communication practitioners and from case studies. Results from the Clark University survey of EPA personnel included a table listing Agency case studies and contacts for successful examples of communication (see Appendix C).

Key Concepts

- Communicating with the public occurs throughout the process, ranging from informal to formal communication.
- The Agency has significant experience communicating human health risk to the public.
- The major differences between communicating about human health and ecological issues relate to values, ecoliteracy, and technical issues.

Key Concepts (Continued)

- There is a need to generate more knowledge and interest about ecological issues through education and public outreach programs.
- It is important to involve the public and stakeholders in the process. The public is often an important source of information.
- It is helpful to relate ecological resources at risk to human benefits.
- A variety of resources are available to assist in ecological risk communication.

6. FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT UNIT

Contents

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Summary of Framework for Ecological Risk Assessment Unit

Time Allotted

Approximately 1 hour allowed for discussion and lecture.

Summary of the Unit

This unit presents an overview of the EPA Risk Assessment Forum's *Framework for Ecological Risk Assessment*. It provides a perspective on the *Framework's* history, objectives, and major concepts. The importance of communication between the Risk Assessor and Risk Manager is emphasized.

Key Concepts

- The *Framework for Ecological Risk Assessment* provides a rigorous and systematic structure for performing these assessments—a common framework allows for comparable approaches and comparable results across media.

- To be useful as one tool in decision making, risk assessments must be relevant to regulatory needs and public concerns and have scientific validity.

- Communication between the Risk Assessor and Risk Manager is critical to the success of the risk assessment.

References

USEPA. 1992. *Framework for Ecological Risk Assessment*. EPA/630/R-92/001. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

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Framework for Ecological
Risk Assessment Unit

This unit will provide:

- An historical perspective of the *Framework for Ecological Risk Assessment*;
- An overview of the major concepts contained within the *Framework*;
- Insights on the roles of risk assessors and risk managers in the process; and
- Application of the framework at the ecosystem level.

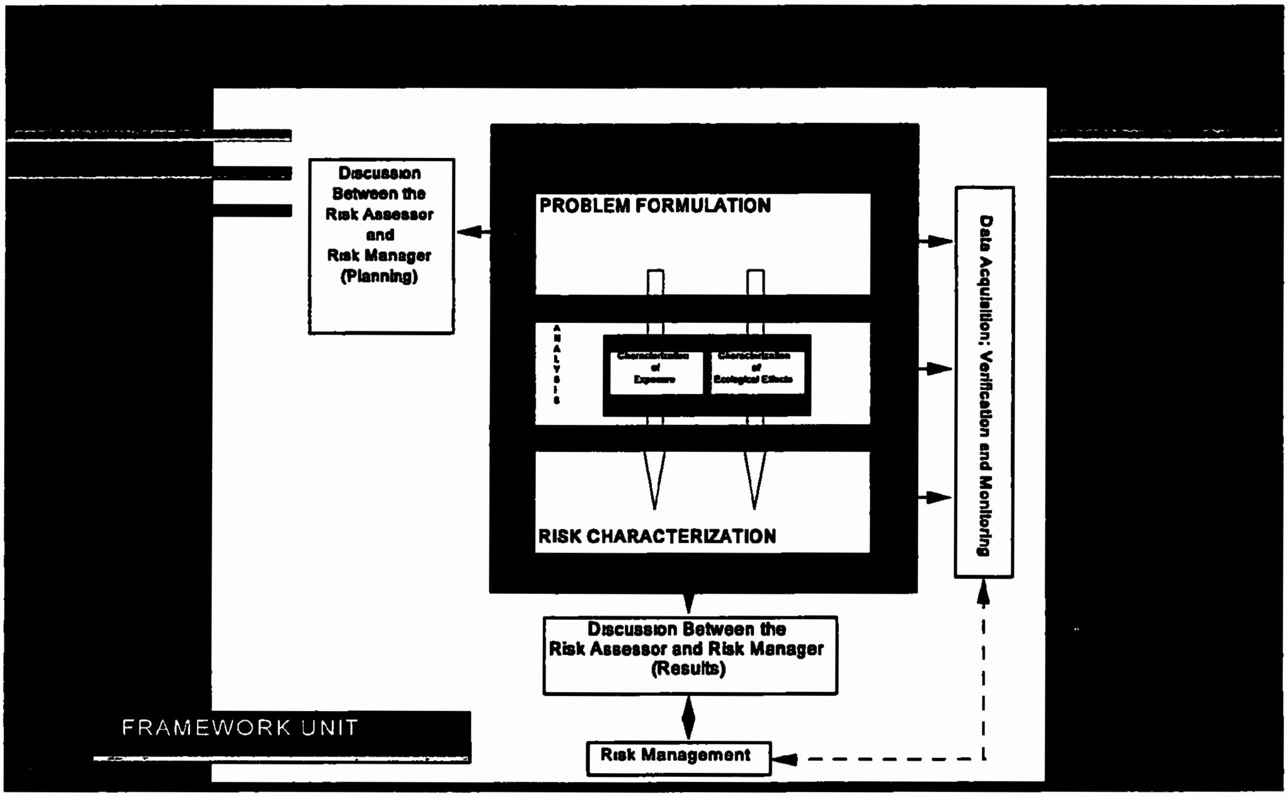
Why was the Ecological Risk Assessment Framework developed?

Beginning in the early 1980s, the Agency realized an increasing need to set priorities among complex environmental problems and saw risk as one way to help. As the Agency adopted a risk-based approach, it looked for a clear, consistent mechanism for addressing ecological risk.

In 1988, the EPA began developing ecological risk assessment guidelines as a parallel effort to the human health risk assessment guidelines under the direction of the Risk Assessment Council. The Agency, working with the National Academy of Sciences (NAS), determined that the 1983 NAS risk assessment paradigm approach, with significant modifications, could work for ecological risk.

During a review of this effort by the Science Advisory Board (SAB) and the Risk Assessment Forum (RAF), it became clear that a common structure and terminology for ecological risk assessments was needed before detailed guidelines could be developed. The recommendation of both the SAB and the RAF was to develop a background document on what the overall process should look like, including an attempt at standard terminology. The result was the *Framework* document.

Currently, the RAF is developing detailed ecological risk assessment guidelines which will address issues associated with the use of the framework, such as, how to deal with the relative risk of multiple stressors and how to deal with uncertainty.



What Is the Framework?

The *Framework* was developed by EPA's Risk Assessment Forum, a standing committee of EPA scientists charged with developing risk assessment guidance for Agency-wide use. It is a simple, flexible structure for conducting and evaluating ecological risk assessments within EPA. It is not a procedural guide or a regulatory requirement.

As a broad outline of the assessment process, the *Framework* offers a basic structure and starting principles around which program-specific guidelines for ecological risk assessment can be organized. With this in mind, the *Framework* does <u>not</u> provide substantive guidance on factors that are integral to the risk assessment

What Is the *Framework*? (Continued)

process, such as analytical methods, techniques for analyzing and interpreting data, or guidance on factors influencing policy.

- The process described by the *Framework* **provides wide latitude** for planning and conducting individual risk assessments in many diverse situations, each based on the common principles discussed in the *Framework*.

- The process will help: (1) **foster a consistent EPA approach** for conducting and evaluating ecological risk assessments, (2) **identify key issues**, and (3) **provide operational definitions** for terms used in ecological risk assessments.

- The process also provides a systematic structure for the risk manager and risk assessor to discuss ecological risks using common terms.

The *Framework* consists of three major phases:

Phase 1-Problem Formulation. A planning phase and scoping process that establishes the goals, breadth, and focus of the risk assessment.

Phase 2-Analysis. Develops profiles of environmental exposure and the effects of the stressor.

Phase 3-Risk Characterization. Integrates the exposure and effects profiles to evaluate the likelihood of adverse ecological effects associated with exposure to a stressor.

Problem Formulation

- **Planning phase that establishes goals, breadth, and focus for the assessment.**
- **Regulatory and policy considerations are determined.**
- **Communications between Risk Assessor and Risk Manager are important.**
- **Public involvement is essential.**

Problem Formulation

Introduction

Ecological risk assessment provides a methodology to help assess the risk from an action (or inaction) to some specified component(s) of the ecosystem. The first phase of ecological risk assessment— the **problem formulation phase**—is a structured process that allows the Risk Manager to identify what the ecological problems or concerns might be, and how those problems might have been created (or how they might be avoided). The Risk Manager might learn about ecological problems through:

- Discussion with the Risk Assessors;
- Calls from the public reporting an environmental incident or accident such as an oil slick, tastes or odors from groundwater, or a chemical spill;
- Reports in the media about an environmental incident such as a fish or bird kill, damaged wetland, or killed vegetation; and
- Public meetings.

Ecological Effects and Stressors

The problem formulation phase is the step where the Risk Assessor and Risk Manager will work to "put two and two together" to develop theories about the possible relationships between undesirable **ecological effects** and observable **stressors**.

Problem Formulation (Continued)

Stressors

A **stressor** is any physical, chemical, or biological entity that can induce an adverse effect. Examples of **physical stressors** include dredging and filling which results in the loss of physical habitat for a species or group of species. **Chemical stressors** include toxic chemicals, nutrients, or organic materials that may induce high biological oxygen demand. Examples of **biological stressors** include microbiological pathogens or introduced species that compete with or prey upon indigenous species.

Ecological Effects

Ecological effects can be lethal and sublethal (reproductive effects, changes in growth rates, behavioral changes, etc.). While some ecological effects may be so obvious that they are readily observable, some subtle ecological effects (e.g., contamination in a food chain, loss of non-charismatic but ecologically important species, periodic or subtle sublethal changes in the chemical or physical habitat) can result in a slower and less dramatic decline in key species and ultimately to loss of an ecosystem's structure and function.

The Risk Manager will most often have to rely on the Risk Assessor to help develop an understanding of the significance of a stressor or a series of stressors on individual species or on ecosystems.

Developing a Conceptual Model

A conceptual model is useful to identify ecological concerns to be assessed. The conceptual model allows you to relate stressors to all the possible effects by tracing possible exposure pathways in the ecosystem. These models may take the form of sketches of the ecosystem at risk (cross-section or plan view), with arrows illustrating routes of exposure, or they may be abstract in form, with ecosystem components and stressors in boxes with arrows showing relationships between them.

Public Involvement

The Risk Manager must ensure that the risk assessment is relevant to societal as well as regulatory needs. Therefore, it is important for the Risk Manager to include **input from the community** in the problem formulation phase. This enables the decision maker to obtain the local scientific expertise or knowledge of the ecosystem at risk, and identify community ecological and economic concerns.

A dialogue that includes the public stakeholders and the Risk Assessor provides the opportunity for public input and public education. The Risk Assessor has an essential role in translating the community ecological values into factors that could be and should be assessed. For example, the public may often interpret charismatic species (bald eagles, herons) as important without fully including the ecological links that sustain them. On the other hand, the public may overlook non-charismatic rare and endangered species that must be protected because of the requirements of the law, such as the Endangered Species Act. The Risk Assessor helps the public understand the ecological interdependence of obviously valued resources with less obvious but equally important species.

Problem Formulation (Continued)

What to Assess?

Together, the Risk Assessor and Risk Manager identify one or more ecological concerns that are to be assessed. Criteria include:

- Presence of or sensitivity to stressors of concern;
- Ecological relevance;
- Policy goals; and
- Societal values.

Examples of these ecological concerns to be assessed could include sustainably reproducing populations of trout species, maintenance of reproductively successful songbird populations, or maintenance of aquatic vegetation populations that are supportive of fish and invertebrates.

How Do We Measure These Concerns?

The Risk Assessor usually will determine how to measure the ecological concerns. The measurements will relate a response to a stressor (effects), and characterize the stressor distribution (e.g., concentration of a chemical in water or in an organism's tissue). For the self-sustained freshwater fishery, we may use models to measure the population effects of the particular stressor in relation to any existing stressors or pressures on the fishery (natural or man-made). Other types of measurements include toxicity, bioaccumulation, abundances and diversity of organisms, mortalities, production, and acres of habitat.

Analysis

- **Analysis consists of evaluation of exposure and effects.**
- **Risk Managers need to understand the analysis to make better decisions and be able to explain them to the public.**

Risk Analysis

The risk analysis consists of an evaluation of potential or past exposures and their association with predictable or observable ecological effects. This analysis is based upon the conceptual model developed in Problem Formulation. It is unlikely that a Risk Manager will ever have to conduct a risk analysis since it usually is the work of the Risk Assessor or risk assessment team. It is useful, however, for the Risk Manager to have an understanding of all that is required for the analysis for the following reasons:

- Understanding the requirements and steps of the analysis will help the Risk Manager to better judge the resources needed for its completion.
- Understanding the basics about risk analysis is helpful in understanding the risk assessment results and how they may be used in decision making.
- Understanding the basics about risk analysis will help the Risk Manager to understand the significance of uncertainties and assumptions in the assessment, as well as the role of professional judgment by the Risk Assessors.
- An understanding of the analytical process will help the Risk Manager explain to the public the results of the risk analysis and how they were used in decision making.

Risk Analysis (Continued)

Risk analysis includes:

- A characterization of the likelihood of exposure to the organism(s) of concern, including a consideration of the spatial and temporal distribution of the stressors. For example, a migratory species may not be present when a chemical spill occurs or a stressor may affect several ecosystems, e.g., acid rain.

- A characterization of ecological effects to assess the likely range of effects resulting from the expected exposures. This involves integration of available information about the organisms or ecosystems of concern with applicable data on responses from literature, laboratory, or field studies (e.g., data on mortality, such as fish kills, bird kills), and reproductive failures (e.g., loss of certain or most recent age classes, deformities, egg shell thinning, etc.). This may result in identification of the relationship between the level of exposure and effect, and may establish the presence of a cause-effect relationship, or at least a preponderance of evidence that associates the presence of the stressor with the occurrence of the ecological effect.

Risk Characterization

- **Estimates risk incorporating uncertainty.**
- **Risk Managers need an understanding of uncertainty to make and communicate a decision.**
- **Risk is described in terms of ecological significance.**

Risk Characterization

Risk characterization is the final phase of risk assessment. It evaluates the likelihood of adverse effects occurring as a result of exposure to one of more stressor(s). It provides an integration of the exposure profile and the ecological effects profile from the analysis phase. It estimates the effects of uncertainties on the analysis results and summarizes them for consideration in the risk management process.

A key process in the characterization of risk is the development of an uncertainty analysis—to provide at least a qualitative, but better yet, a quantitative estimate of how uncertainty in the analysis or underlying assumptions can effect the assessment of risk.

The Risk Manager needs to understand the uncertainties in the assessment to consider the weight that must be given to the assessment in decision making.

The Risk Manager also needs to explain the uncertainties of risk assessment results to a public that often views scientific information in black and white rather than in probabilistic terms.

For the public to understand how risk assessment information is used in decision making, they need to understand that uncertainties themselves do not necessarily invalidate assessment results. Knowing what is uncertain or unknown can be just as useful as known data.

Risk is described in terms of its ecological significance. For example, how significant is the loss of 5 acres of wetland in a particular ecosystem? Are the magnitude of effects (i.e., over space and time) significant to the species, population, or ecosystem? Can the ecosystem recover? Ecological significance is determined by environmental statutes and policy as well as knowledge of the ecosystem.

Communicating Risk Assessment Results: Discussions Between the Risk Assessor and the Risk Manager

- **Understanding of spatial and temporal extent of risk and recovery potential.**
- **Understanding of strengths, limitations, certainties, uncertainties, and assumptions encountered during the analysis.**
- **Providing information necessary for effective communication to the public.**

Discussion Between the Risk Assessor and Risk Manager

The discussion between the Risk Manager and Risk Assessor about the results of the risk assessment is important for many reasons:

- The Risk Manager is given a clear understanding of the spatial and temporal extent of the stressors, their sources and the effects and, whenever possible, recovery potential.
- It creates a clear understanding of the strengths, limitations, certainties, uncertainties, and assumptions encountered during the analysis.
- It provides the Risk Manager with information necessary to perform effective communication—to explain issues relating to ecological significance and how they were used to strengthen the assessment or rationale for the decision.

Middle Snake River Watershed: An

Ecosystem Risk Assessment

An Application of the Framework at the Ecosystem Level

Ecological risk assessment can be applied toward the assessment of single stressors (e.g., pesticide registration) or multiple stressors (e.g., superfund site, watershed or ecosystem assessment). The watershed or ecosystem assessment focuses on protecting the ecological structure and function of an area by managing existing and future stresses or human uses, thus, making it a useful tool for community-based ecosystem protection.

Background

A watershed ecological risk assessment was applied in the Middle Snake River in south-central Idaho. Historically, the Snake River (a tributary of the Columbia River) was a swift flowing cold water stream that began in the mountains of western Montana and Wyoming and eastern Idaho. As it crossed the arid grasslands of Idaho, in many places it lay deep within a gorge, where its pools and swift flowing water were kept cool. The river and its tributaries were exceptional habitat for migratory Pacific salmon and sturgeon as well as a number of cold-water species that depended on its cold swift-water habitats.

In the last 80 years, however, with the advent of human development in south-central Idaho or what is known as the *Magic Valley*, the area has changed:

- Over a dozen dams in the middle reaches of the river generate hydropower and divert river water for irrigation (e.g., at American Falls, ID the *entire flow* of the river is often diverted for these uses). Fish migrations are blocked and habitat destroyed by the creation of impoundments and loss of rapids area within the stream flow.

Application of the Framework at the Ecosystem Level (Continued)

Background (Continued)

- Hundreds of fish farming (aquaculture) operations divert cool, nutrient-poor spring water through rearing tanks and discharge warmed, nutrient-rich, high biochemical oxygen demand (BOD) water into the river.
- Large areas of the watershed have been converted to irrigated, tilled agriculture. Water returning from irrigation channels and runoff from the land contain sediments, nutrients, and pesticides.
- The development of cities and towns and associated industries added municipal sanitary and industrial discharges to the river.

The result of these changes has been the loss of all migratory salmon species; the reduction of other cold-water aquatic species, including rare and endangered benthic invertebrate species; and the rising dominance of pollution-tolerant and exotic species within the mid-Snake River region.

Problem Formulation: Public Involvement, Regulatory Concerns, and Management Goals

Even as pressure continued for further development on the river (e.g., the impoundment of the last segment of river with swift water and cold, well oxygenated pools), there was a great interest by the people in the surrounding area to 1) protect and restore a healthy cold-water fishery for at least non-migratory species because of its recreational resource value; 2) preserve some of the traditional linkages between people and the ecology that were important historically; 3) preserve the natural beauty of this great western river and 4) identify levels and types of economic activity that were sustainable within those environmental goals.

To address these issues, the State of Idaho, through its state agencies, began to prepare a nutrient management plan. The plan would be designed to address the EPA requirement for the establishment of discharge permitting based upon a Total Maximum Daily Load (TMDL) estimate for nutrients, sediments, and BOD to re-attain the designated use (fishable, swimmable) of this stream segment. As part of this process, the Idaho Department of Environmental Quality (DEQ) held hearings in south-central Idaho to identify the citizens' goals for environmental protection. The citizen-stakeholders had great concern for the economic well-being of the area but recognized the important role that the ecology of the area plays in the well-being, quality of life, and economy of the valley. There was also a concern by many stakeholders about the impacts on the way business-as-usual is done, since improvements to support the ecology of a cold water stream would very likely affect the many prevailing uses of the stream.

Application of the Framework at the Ecosystem Level (Continued)

Problem Formulation: Public Involvement, Regulatory Concerns, and Management Goals (Continued)

The management goals that were identified represented a combination of concerns:

- *Societal Values* - including the perceived aesthetic and economic value of the ecosystem;
- *Statutory mandates* - re-compliance with water quality standards, protection of endangered species, and;
- *Ecological Relevance* - restoration and protection of important habitat for an ecosystem dominated by a cold water fishery.

Analysis

The Idaho DEQ, with assistance from EPA Region 10, the University of Idaho, and Idaho State University conducted an assessment of the current state of the ecosystem focusing on the conditions within the stream relevant to the species of concern. EPA Region 10, along with the I-DEQ, then began a characterization of conditions that would be required to support the **cold water fishery** as well as the **endangered invertebrate species.** The analysis focused on identification of current conditions and the thresholds that would be necessary to restore and protect the conditions necessary for those species to survive and reproduce. Environmental measurements included water temperature and chemistry, a characterization of sediment and rates of sedimentation under varying flow conditions, and other aspects of desirable habitat such as the amount of hard bottom habitat lost to sedimentation and nuisance aquatic plant and algal growth, and dissolved nutrient regimes that support those nuisance growths.

Risk Characterization

Risk characterization will focus on identification of the thresholds of flow, sedimentation, and nutrient addition that would provide favorable conditions for the cold water fishery (trout species) and endangered cold-water benthic invertebrates.

Risk Management and Decision Making

Ultimately, management strategies based upon the risk characterizations would also have to recognize that these three stressors are related under most conditions in the river. An optimum management strategy would be one that achieved the risk thresholds with the least cost of implementation and fewest negative economic (or perhaps greatest positive) impacts.

Key Concepts

- The *Framework* is a systematic structure to perform ecological risk assessments, and provides for comparable approaches and results across media.
- Risk assessments must be relevant to regulatory needs and public concerns while maintaining their scientific validity.
- Communication between the Risk Assessor and Risk Manager is critical to the success of the risk assessment.

7. Pesticide

7. PESTICIDE SPECIAL REVIEW

GROUP EXERCISE
WormFree Granules

Contents

Case Study Background and Information Sheets

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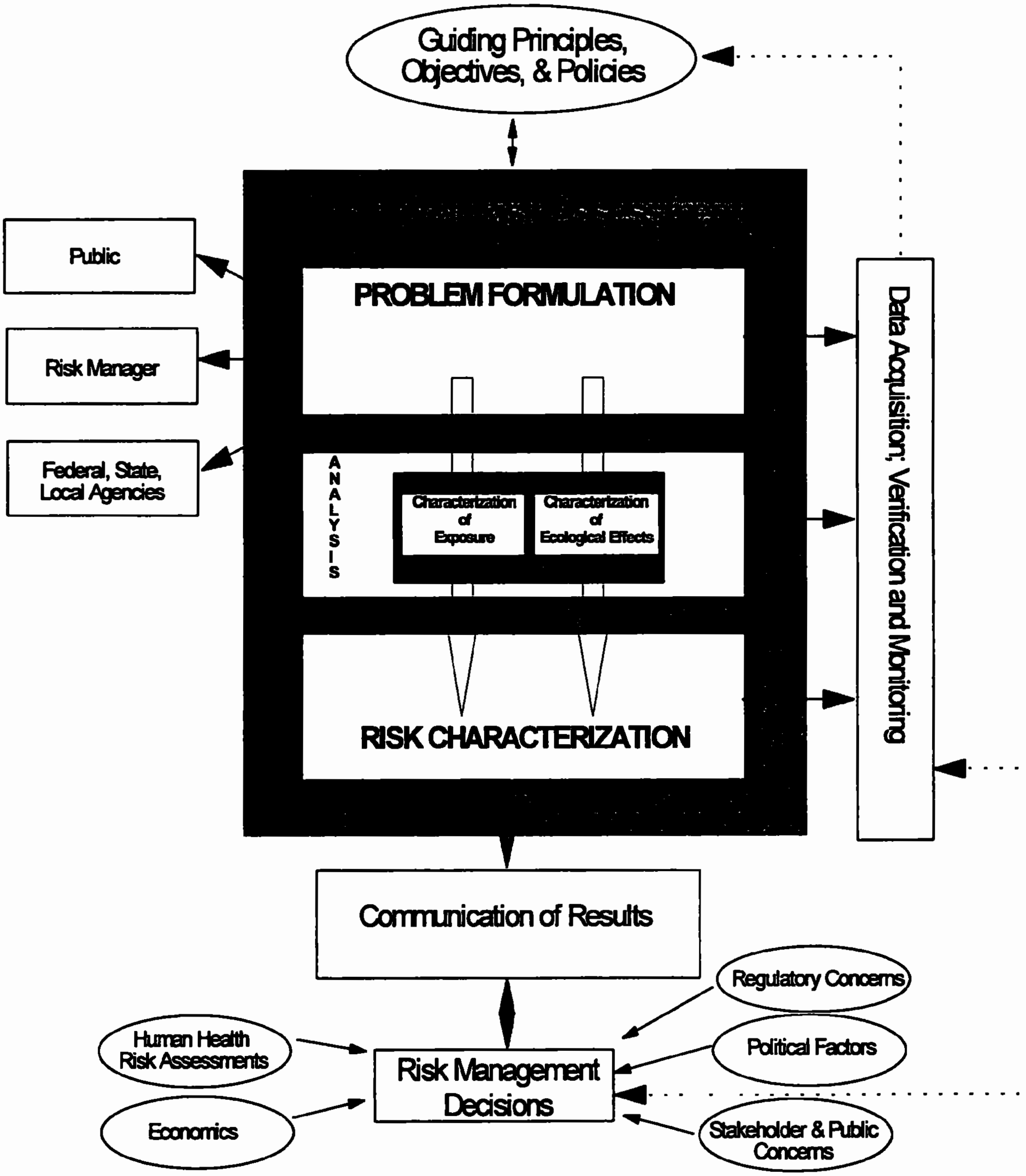
Guiding Principles, Objectives, & Policies
Public
Risk Manager
Federal, State, Local Agencies
PROBLEM FORMULATION
ANALYSIS
Characterization of Exposure
Characterization of Ecological Effects
RISK CHARACTERIZATION
Data Acquisition; Verification and Monitoring
Communication of Results
Regulatory Concerns
Human Health Risk Assessments
Political Factors
Risk Management Decisions
Economics
Stakeholder & Public Concerns

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OVERVIEW OF THE GROUP EXERCISES

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Overview of the Group Exercise

Summary of Group Exercise

In this exercise, you will conduct an ecological risk assessment for the granular formulation of WormFree. At the conclusion of the exercise, you will have four options to consider with regard to the registration of granular formulations of WormFree: (a) cancellation, (b) suspension, (c) modification of the terms and conditions of registration, and (d) continuation without modification.

Phases of the Group Exercise

The exercise will be conducted in four separate phases, with a report-out at the conclusion of each phase. These phases will focus on:

1. Problem Formulation
2. Analysis
3. Risk Characterization
4. Decision Making

Materials in This Package

- *Work Sheets.* Work Sheets will guide you through the exercise. Each Work Sheet includes questions or problems for group discussion. Your group should proceed through the Work Sheets in the order they are presented.

- *Information Sheets.* Information Sheets present information on the case study needed for the exercise. This information includes the basic case study background as well as additional case information that will be needed for each of the sessions.

Group Exercise Process

- The Facilitator will gather participants into groups. Each group will choose a leader, a recorder and one person to report out the group's recommendations and conclusions.

- Your group is to assume two roles. For the first 3 phases, your group will complete a risk assessment and communicate results to the decision maker. For the last phase, Decision Making, your group will change roles and integrate results of the risk assessment with other information needed to reach a management decision.

- Group members will collaborate to develop answers to questions presented on the Work Sheets. You will present your findings to the rest of the workshop participants during the discussion sessions.

Overview of the Group Exercise (Continued)

References

Suter, G.W., II. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea, Michigan.

USEPA. 1992. Framework for Ecological Risk Assessment. EPA/630/R-92/001. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

BACKGROUND ON CASE STUDY

Background on Case Study

Time Allotted

Approximately 30 minutes to read.

Purpose of Case Study

The purpose of the case study is to determine future use of a pesticide used on corn. The first steps will be to establish the likelihood of adverse ecological effects. The final decision making will consider other relevant factors.

Location

WormFree is a granular worm control compound applied to approximately 5 million acres of corn, primarily in the Great Plains Midwestern States, but also in other places throughout the United States. It is generally applied during the spring planting season.

Corn is associated with a variety of habitats. These habitats often are transitional, occupying the edges around cultivated land, and are composed of several layers of vegetation which supply food and shelter for a variety of animal species.

Nature of the Problem

WormFree is a broad-spectrum pesticide registered for corn. EPA noted at the time of the original registration in the early 1970s that WormFree was highly toxic to wildlife, especially birds, based on available laboratory data. Despite this information, EPA registered the pesticide for use on corn.

Since registration of WormFree, incidents involving dead and dying birds following the application of WormFree granules began to be reported in the early 1970s. As this trend continued, some farmers in Indiana reported these findings to their state agricultural agency. After a while, concerned citizens and State personnel became aware of these incidents, and the number of reports multiplied.

The number of reported bird kills associated with the application of WormFree granules finally reached a threshold and led EPA's Office of Pesticide Programs (OPP) to conduct a risk assessment. Your team is tasked with designing and conducting this risk assessment, then changing roles to decide whether the registration status should be changed.

Background on Case Study (Continued)

OPP received documentation of more than 40 incidents of WormFree-related bird kills involving nearly 30 species of birds. The number of birds involved in any single incident ranged from 1 to more than 2,000, with all but two kills attributed to use of the chemical according to label instructions. Based on these incident reports, the Agency required field studies in which the mortality of birds after WormFree application was investigated on a systematic basis.

Stressor Characteristics

Chemical Characteristic

- WormFree is somewhat water soluble.

Application Method

- WormFree is generally applied when seeds are planted at the beginning of the spring growing season to prevent pest damage that may occur after germination.

- Small granules, approximately the size of sugar grains, are applied with ground equipment that results in some granules remaining exposed on the soil surface.

Effects

- WormFree is an acute toxicant that affects the nervous system. It can cause human symptoms of headaches, salivation, abdominal pain, drowsiness, dizziness, anxiety and vomiting.

- There have been no reported cases of adverse human health effects after consumption of corn treated with WormFree.

- Experimental studies show that WormFree inhibits acetylcholinesterase, a neurotransmitter.

- Field evidence indicates that WormFree may cause bird mortality up to 60 days after first application.

Environmental Fate and Transport

- WormFree is a highly mobile pesticide, and has the potential to leach because it is somewhat water soluble.

- Residues of WormFree have been found in earthworms and fish after the chemical has been applied to crops nearby.

Background on Case Study (Continued)

Pertinent EPA Program Office

- Office of Pesticide Programs (OPP)

Statutory Requirements Under FIFRA

A pesticide product may be sold or distributed in the United States only if it is registered or exempt from registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended. Before a product can be registered unconditionally, it must be shown that it can be used without causing "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs, and benefits of the use of the pesticide." Thus the health and environmental risks are balanced against the economic benefits gained from using the pesticide.

EPA can review the status of a registered pesticide if there is evidence that use of the pesticide may raise an "unreasonable risk" as defined above. The options open to EPA include:

- **Suspend registration.** If EPA determines that *any* continued use poses an imminent hazard to health or the environment, it can suspend the registration and call in all existing stocks for disposal.

- **Cancel registration**. Cancellation means that EPA will no longer allow the pesticide to be used for the specified purpose. However, existing stocks of the pesticide can be used up. The trigger for cancellation is when use of the pesticide according to its labeling "generally causes unreasonable adverse effects on the environment."

- **Modify the terms and conditions of registration.** Modification of the terms and conditions entails changing the amount applied, the timing, or method of application allowed, or restricting use to specially trained personnel known as "certified applicators." Such changes would be used to reduce the risks associated with the pesticide while retaining the benefits of its use.

- **Continue registration without modification.**

Endangered Species

The U.S. Fish and Wildlife Service (FWS), a branch of the Department of Interior, is the Federal agency responsible for administering the Endangered Species Act (ESA) of 1973. EPA must consult, either formally or informally, with the FWS if EPA determines that its action may effect a threatened or endangered (listed) species or its designated critical habitat. These EPA actions could include registration of a pesticide and any other decision authorized, funded or implemented by EPA. Also, EPA must confer with the FWS if its action could affect a species or critical habitat that may be proposed for listing. If EPA determines that there will be no effect, consultation is not necessary.

Background on Case Study (Continued)

Public Involvement

EPA typically publishes a summary of its assessment of the risks and benefits of a pesticide in the Federal Register and allows a 90 day public comment period. Press advisories, Fact sheets, and Questions and Answers are also developed and sent to all those on the extensive mailing list. A communications strategy is developed to ensure that other offices within EPA and groups with interest in the specific compound or issue are contacted, and frequently constituent briefings and news conferences are held. EPA regions and State pesticide authorities are always advised of proposed pesticide decisions, usually through monthly conference calls. A final notice responding to public comments and detailing the Agency's final decision is also published in the Federal Register.

Decision Options

At the conclusion of this exercise, your team will decide among the following options:

- Continue registration without modification;
- Modify the terms and conditions of registration;
- Suspend registration; or
- Cancel registration of the granular formulation of WormFree.

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PROBLEM FORMULATION

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Problem Formulation

Contents

Work Sheets (WS)

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Problem Formulation Exercise

Time Allotted

Approximately 2 hours.

Key Concepts

- Problem formulation establishes the objectives and scope of the ecological risk assessment.
- The Risk Assessor should work with the Risk Manager to identify the objectives and scope of the risk assessment and the assessment endpoints. The Risk Assessor should be aware of the kinds of information needed by the Risk Manager to make a decision.
- An assessment endpoint is a formal expression of the environmental value to be protected and should be ecologically relevant, reflect policy goals and societal values, and be susceptible to the stressor.
- A measurement endpoint is a measurable response to a stressor that is related to the assessment endpoint.
- The public should be involved in selecting assessment endpoints and contributing information.
- The selection of assessment endpoints must be focused to meet the needs of the investigation while reflecting the availability of resources (personnel, financial, time).

Activities

- Identify and select ecological concerns.
- Develop a simple conceptual model.
- Identify and select assessment and measurement endpoints.

Task Overview

- Complete the Work Sheets in numerical order. Refer to the Information Sheets as needed.
- Choose a leader and spokesperson to make notes on the flip chart and present a summary of the group discussion. This can be two people or one person can fill both roles.

Problem Formulation Phase

The Problem Formulation Phase is where the planning for an ecological risk assessment takes place. The goals, breadth, and focus for the assessment are established in this phase, taking into account regulatory, policy, and public concerns. The Risk Manager and Risk Assessor work together to identify the ecological concerns or effects that are expected or have resulted from a particular activity or pollutant regulated by EPA (e.g., Superfund clean-up, RCRA corrective action, pesticide use, new chemical registration, filling wetlands, or discharging pollutants into waterways).

Public input at this stage is important because, the public often has concerns and knowledge that will improve the assessment. Also, public input is often required by law. In addition to determining what to assess, decisions are made as to how to assess (i.e., literature search for information, measurements in the laboratory or field, etc.). Factors such as time, cost, and cooperation from other parties are considered when determining how to assess the problem.

Following are some concepts, terminology and tools useful in planning an ecological risk assessment.

Stressors

Stressors are the pollutants or activities that cause the ecological concern or effect.

Generally, the *Framework* classifies stressors as being chemical, physical, or biological. Examples include:

- Chemical—toxics, nutrients (nitrates in water);
- Physical—dredging or filling in waterways or wetlands, diverting water flow in a river by constructing a diversion or dam; and
- Biological—introducing exotic organisms.

Exposure Routes or Pathways

It is important to trace exposure routes or pathways of a stressor to determine all the possible components of the ecosystem that may be affected. Considerations include:

- Mobility of a stressor;
- Uptake of a chemical by plants and animals;

Problem Formulation Phase (Continued)

Exposure Routes or Pathways (Continued)

- Transformation (chemicals may degrade in the environmental from exposure to light or react with water or other chemicals to form substances that are non-toxic, less toxic, or more toxic than the original chemical); and

- Competition (biological stressors).

For physical stressors, the exposure may be immediately obvious (i.e., removing or destroying ecosystems by building a structure, dredging, or removing water for agriculture or drinking water supplies). The effects of physical stressors may be far-ranging, e.g., removal or diversion of water alters habitats downstream (bays become saltier, adversely affecting bay fish nurseries which require a mixture of fresh and salt water).

Ecological Effects

Ecological effects are the harmful responses of the ecosystem and its components to exposure to stressors. Some examples include death, reproductive failure, decline in growth rate, habitat loss, etc.

Conceptual Models

Conceptual models are helpful in fully characterizing the ecological effects associated with stressors. These models may take the form of sketches of the ecosystem at risk (cross-section or plan view) with arrows illustrating routes of exposure, or they may be abstract in form with ecosystem components and stressors in boxes with arrows showing relationships between them.

Assessment Endpoints

The *Framework* uses the term assessment endpoint to identify the ecological concern(s) that will be the focus of the assessment. Criteria used to select assessment endpoints include:

- Sensitivity to stressors of concern;
- Ecological relevance; and
- Relevance to policy goals and societal values.

The assessment endpoint needs to be both affected by and sensitive to the stressor(s). Ecological relevance means that the assessment endpoint is important to the function of the ecosystem. For example, lake trout play an important role in maintaining the balance of aquatic ecosystems. However, the introduction of carp has disrupted the balance of aquatic ecosystems.

Problem Formulation Phase (Continued)

Assessment Endpoints (Continued)

Assessment endpoints also should reflect policy goals (e.g., protect endangered species and no net loss of wetlands). Societal values helped form the basis for these policies when environmental laws were enacted. However, policy or management goals (e.g., protect endangered species, maintain recreational fisheries) are not assessment endpoints.

Assessment endpoints must be measureable. Examples of assessment endpoints include: sustainably reproducing populations of trout species; maintenance of populations of aquatic vegetation that are supportive of fish and invertebrates; maintenance of reproductively successful songbird populations, etc. The more specific the assessment endpoint the better (e.g., loss of no endangered bats).

Measurement Endpoint

Measurement endpoint is another term used in the *Framework* referring to how we determine exposure and effects to an assessment endpoint. Examples of what to measure include concentration of a chemical in water and animal tissue, number of offspring, deformities, mortality, acres of wetlands removed, modeled impacts to a specific population, etc.

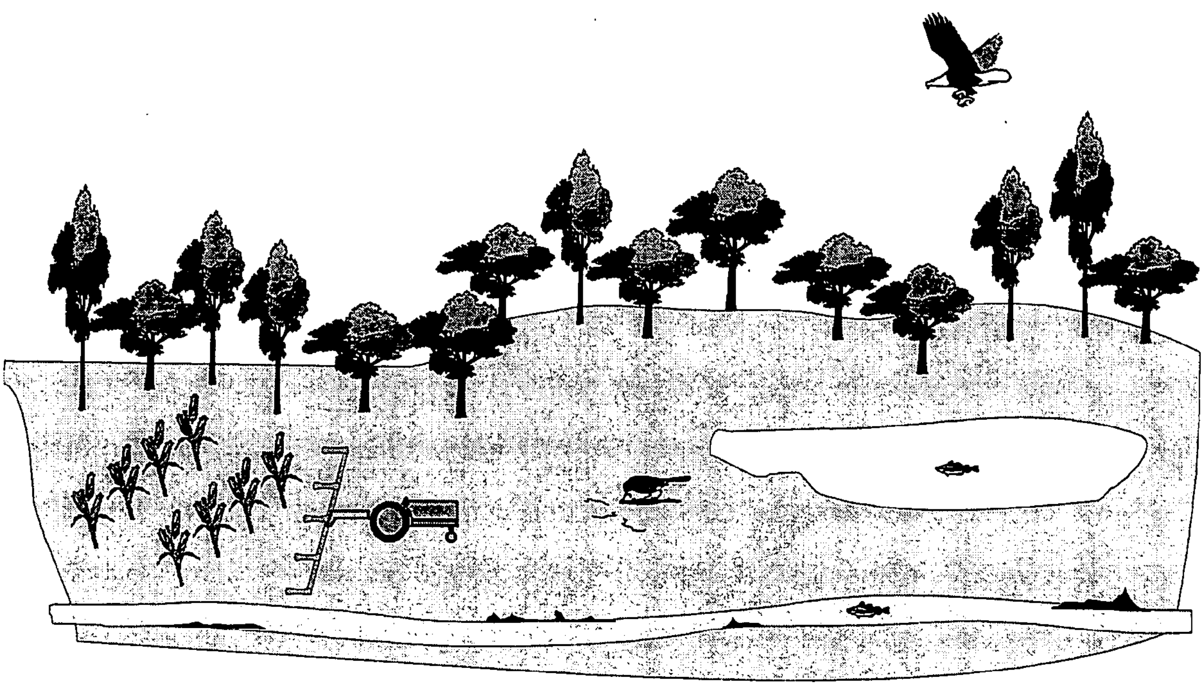
PROBLEM FORMULATION WORK SHEET #1

Scoping and Selecting Exposure Pathways and Ecological Components By Developing a Conceptual Model

1. Based on your knowledge of the stressor (WormFree), its use, and the nature of the problem, prepare a list of ecological components (individuals, populations, communities, etc.) that might be affected by the application of WormFree granules by sketching the relationships among the stressor, exposure route, and ecological components in the diagram below. Bear in mind the concepts covered during the *Ecology Unit* and the background material on stressor characteristics as you discuss and list the possibilities.

   Here are some ideas to help focus your thinking:

   - The most direct way that an animal might be exposed to WormFree granules would be through ingesting them. What kinds of animals might do that and why?
   - What environmental media (air, soil, surface water, ground water, sediment) are likely to contain concentrations of WormFree and why? What kinds of organisms might come into contact with contaminated media?
   - What happens to organisms that have been killed or made ill by WormFree? What animals eat them?
   - What impact would exposures have on endangered species or their habitat?



PROBLEM FORMULATION WORK SHEET #2

Identifying and Selecting Assessment Endpoints

1. With the list of ecological components on Problem Formulation Work Sheet #1, and develop 3-4 assessment endpoints.

Ecological Components

PUBLIC INPUT

EPA spoke to State environmental and conservation officials to begin to identify available sources of information. One State had files with information from local citizens reporting bird kills and local knowledge of that habitat. State personnel confirmed the presence of endangered species, including the Bald Eagle and the Indiana Bat. Other information provided by the citizens has not been investigated.

Assessment Endpoints

PROBLEM FORMULATION WORK SHEET #3

Identifying and Selecting Measurement Endpoints

1. Prepare a list of measurement endpoints for the 3-4 assessment endpoints.

Assessment Endpoints	Measurement Endpoints

2. What types of activities would be required to obtain data about the selected measurement endpoints? What are the real world constraints on an ecological risk assessment, and how could these constraints affect your ability to carry out these activities?

ANALYSIS

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Analysis

Contents

Work Sheets (WS)

WS #1: Analysis of Exposure
WS #2: Analysis of Ecological Effects

Information Sheets (IS)

IS #1: Application Information
IS #2: Number of Exposed WormFree Granules After Band Application
IS #3: Representative Bird Species Likely to Be Exposed to WormFree Based on Field Observations
IS #4: Summary of Reported Bird Kill Incidents Associated with Application of WormFree to Corn Fields (1972-1987)
IS #5: Summary of Bird Kill Incidents Due to Secondary Poisoning From WormFree Granules on Corn (1983-1986)
IS #6: Laboratory Acute Oral Toxicity (LD_{50}) Values of WormFree
IS #7: Field Study of Bird Kills After Application of Granular WormFree to Corn

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Summary of Analysis Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- The major components of the Analysis Phase are characterization of exposure and characterization of ecological effects.
- Exposure analysis requires knowledge of: (1) stressor characteristics (physical, chemical, and biological) in environmental media, (2) the probability that ecological components come into direct or indirect contact with the stressor, and (3) the timing of exposure to a stressor in relation to biological cycles.
- Both direct and indirect ecological effects should be addressed.
- Measurement endpoints must be related to assessment endpoints, and this often involves extrapolation from measured individual effects to estimated population and community level effects.
- Risk assessment requires varying degrees of professional judgment in dealing with uncertainties.

Activities

- Analyze exposure routes and pathways, consider stressor characteristics, and identify ecological components of concern.
- Analyze direct and indirect ecological effects.
- Identify uncertainties associated with the analysis phase.

Analysis Phase

The Analysis Phase is where both the exposure and effects of stressor(s) on the assessment endpoints are determined. This phase involves collecting and analyzing data in the literature, actual measurements in the laboratory or field, and modeling. As with any analytical work, there are uncertainties in the data and interpretation of the data. These uncertainties should be documented, carried through the assessment, and presented as part of the results to the Risk Manager. Professional judgement is often a component of ecological assessments, and should be clearly identified when the results are presented to the Risk Manager. Similarly, any extrapolations (e.g., from individual to population to community, from laboratory to the field, or from one place to another) should be identified as part of the uncertainties.

Exposure Analysis

It is important to know how stressors behave in the environment, i.e., how solar radiation, water, sediments, soil, and air and the living components affect the movement and form stressors take in the environment. For example, non-affected organisms may metabolize toxic chemicals to non-toxic compounds. Both direct and indirect exposure should be analyzed. An organism may become exposed to a toxic chemical by eating a contaminated organism rather than by direct exposure (consider predator species). Temporal and spatial distribution of a stressor is important. The stressor might affect a certain life stage or the entire life cycle of an organism. The extent of exposure to a stressor could be localized or affect an entire region or large ecosystem.

Effects Analysis

Both direct and indirect effects should be analyzed. Often, indirect effects are difficult to ascertain. Examples of indirect effects are when organisms affected by a stressor are prone to disease, easier targets of prey species, and less competitive.

ANALYSIS WORK SHEET #1

Analysis of Exposure

Read Analysis Information Sheets #1 - #3 before answering the following:

1. Which media should be considered during exposure analysis? Why? How does the information you have now supplement, reinforce, or change the view you developed with your conceptual model?

2. What is the exposure route (i.e., the way the chemical enters the organism)?

ANALYSIS WORK SHEET #1 (Continued)

Analysis of Exposure

3. How could timing of the pesticide application relate to exposure?

4. Are there uncertainties associated with your answers to the questions above, given the data available? What are they?

ANALYSIS WORK SHEET #2

Analysis of Ecological Effects

Information you will need for this work sheet is contained in:

Information Sheet #4	**Summary of Reported Bird Kill Incidents Associated with Application of WormFree to Corn (1972-1987)**
Information Sheet #5	**Summary of Bird Kill Incidents Due to Secondary Poisoning from WormFree Granules (1983-1986)**
Information Sheet #6	**Acute Oral Toxicity (LD_{50}) Values of WormFree**
Information Sheet #7	**Field Study of Bird Kills After Application of Granular WormFree to Corn**

1. What do we learn about the effects of WormFree from each of the different kinds of information provided (incident reports, lab studies, and field studies)?

ANALYSIS WORK SHEET #2 (Continued)

Analysis of Ecological Effects

LD_{50} = Median lethal dose. A concentration or dose at which 50 per cent of test organisms die within a given period of time.

2. What are the advantages, limitations, and uncertainties of each kind of information?

3. What other information would you like to have to understand the effects of WormFree?

ANALYSIS INFORMATION SHEET #1

APPLICATION INFORMATION

GRANULE

Small piece of clay, sand, or other carrier impregnated with a chemical. Granules fall within a specified size range, and vary in color and shape. A granule is slightly more coarse than granulated sugar.

Application Method

WormFree granules are applied as a 7-inch band to the soil surface and then incorporated into the top inch by an incorporation device or by dragging a chain.

Timing of Application

Usually at the beginning of the growing season, in April and May.

Efficiency of Application

Granules may be left on the soil surface after application. Granules also may be left on the soil surface when machinery is being loaded, when planter shoes are lifted out of furrows to permit turning, and when planter shoes rise out of the soils of irregularly contoured fields.

Several investigators confirmed that band application of WormFree or other granular pesticides using conventional application equipment results in exposed granules on the soil surface. One study reported that 5.8 to 40.2 percent of granules remain unincorporated after band application.

ANALYSIS INFORMATION SHEET #2

Number of Exposed WormFree Granules After Band Application

Application Rate (lb AI/acre)	Granules Exposed/ft^2	mg AI/ft^2
1	11	5.5

AI = Active Ingredient

Assumes 0.5 mg AI per granule

ANALYSIS INFORMATION SHEET #3

Representative Bird Species Likely to Be Exposed to WormFree Based on Field Observations[1]

Wading Birds

Great Blue Heron
Snowy Egret
Little Blue Heron
Cattle Egret

Waterfowl

Ducks
Brant
Canada Goose
Teals
Northern Pintail
Northern Shoveler
Gadwall
American Wigeon
Canvasback

Raptors

Vultures
Mississippi Kite
Bald Eagle
Northern Harrier
Hawks
Golden Eagle
American Kestrel
Falcons

Rails and Allies

Black Rail
Sora
Purple Gallinule
American Coot
Cranes

Shore Birds

Semipalmated Plover
Killdeer
Sandpipers
Laughing Gull

Game Birds

Ring-Necked Pheasant
Greater Prairie-Chicken
Northern Bobwhite
Quail
Wild Turkey
Doves
Common Snipe
American Woodcock

Owls

Woodpeckers

Songbirds

Eastern Kingbird
Horned Lark
Blue Jay
American Crow
Raven
Tufted Titmouse
White-Breasted Nuthatch
Eastern Bluebird
American Robin
Brown Thrasher
Northern Mockingbird
Shrike
European Starling
Northern Cardinal
Pyrrhuloxia
Grosbeak
Bunting
Rufous-Sided Towhee
Sparrows
Lapland Longspur
Bobolink
Blackbirds
Meadowlark
Grackle
Brown-Headed Cowbird
American Goldfinch

[1] Information derived from a review of reports from state wildlife agencies on some of the birds associated with corn crops.

ANALYSIS INFORMATION SHEET #4

Summary of Reported Bird Kill Incidents Associated with Application of WormFree to Corn Fields (1972-1987)[1]

Occurrence	Location	Species	Number of Birds
1972	Wisconsin	Songbird	11
1973	Wisconsin	Songbird	3
1974	Indiana	American Robin Eastern Bluebird	22 1
November-December 1974	Canada	Widgeon Pintail	80 54
May 1979	Iowa	Robin	10
May and June 1983	Iowa	Waterfowl Blue Jay Grackle Killdeer	25 10 2 6
August 1983	Indiana	Waterfowl	200
February 1984	Illinois	Canada Goose	Not Known
May 1984	Canada	Lapland Longspur	>2000
June 1986	Indiana	Songbird	12
June 1986	Indiana	Passerines	20
1987	Indiana	Robin	3

[1] Reports from state agencies, provincial government (Canada), Audubon Societies, and the public.

ANALYSIS INFORMATION SHEET #5

Summary of Bird Kill Incidents Due to Secondary Poisoning From WormFree Granules on Corn (1983-1986)

Location	Date	Species	Description
Iowa	1983	Raven	• Two contained residues in the crop up to 8.1 ppm and 38 granules in the stomach • Another exhibited signs of poisoning but did not die
Iowa and Illinois	1984	Red-Shouldered Hawk	• Female found intoxicated after feeding on small mammals and birds; bird was sacrificed; gut contained 47 ug and gastrointestinal tissue 49.6 ug WormFree
Indiana	1986	Bald Eagle	• One adult male dead at base of active nest with 59% brain acetylcholinesterase inhibition[1]; gastrointestinal tract contained 0.64 ppm WormFree • One dead eaglet in nest along with pigeon and grackle remains

Note that the species in this table are predators or carrion eaters, not insect or seed eaters.

[1] **Acetylcholinesterase inhibition** = Decrease in levels of an enzyme that activates acetylcholine, a compound which acts in transmission of nerve impulses to various organ systems. Acetylcholine accumulation increases nerve impulse transmission and leads to nerve exhaustion and ultimately failure of the nervous system.

Uncertainties:

No systematic or reliable mechanism exists for accurate monitoring and reporting of wildlife kills. OPP relies heavily on incident monitoring by states, and state efforts tend to be highly variable. Only a few states have trained and equipped personnel to respond to kill reports and to conduct the thorough investigation necessary to determine the pesticide and application rate used and whether label directions were followed. In addition, few states regularly report bird kills to EPA.

Even if dead birds are found, the observers may not attribute the deaths to a pesticide application. Field evidence indicates that WormFree may cause bird mortality up to 60 days after the first application. Thus, a farmer or other observer not familiar with the site history may not attribute the death to WormFree application. If a person does suspect that a bird may have been poisoned, the individual may not know to whom to report or may believe they may have some liability associated with reporting. Finally, problems associated with the reporting of bird kills are greater for small, less conspicuous songbirds. Many small birds do not form large flocks, and small carcasses disappear more quickly than large ones. As a result, small dead birds are less likely to be noticed than large dead birds, such as waterfowl.

ANALYSIS INFORMATION SHEET #6

Laboratory Acute Oral Toxicity (LD_{50}) Values of WormFree

Species	**LD_{50} (mg AI/kg of body weight)**
Mallard (waterfowl)	2.1
Northern Bobwhite (game bird)	5.04
American Goldfinch (song bird)	6.02

LD_{50} = Median lethal dose. A dose at which 50 per cent of test organisms die within a given period of time.

AI = Active Ingredient

These levels are considered "very highly toxic" because the LD_{50} values are less than 10.

ANALYSIS INFORMATION SHEET #7

Field Study of Bird Kills After Application of Granular WormFree to Corn

Application Rate (lbs. AI/Acre)	Acres Searched	Number of Dead Birds*	Dead Birds/Acre
4	254	87	0.3
1	92	10	0.1
1	34	23	0.7
1	171	92	0.5
-	307	32	0.1
1	214	58	0.3
0.5	NR[d]	5	-

AI = Active Ingredient

* Deaths include, but are not limited to, horned larks, mourning doves, many different species of waterfowl, short-eared owl, savannah and other species of sparrows, ring-necked pheasants, Northern harrier, red-shouldered hawks, American robins.

NR[d] = Not Reported; therefore, deaths/acre could not be calculated.

RISK CHARACTERIZATION

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Risk Characterization

Contents

Work Sheets (WS)

Information Sheets (IS)

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Risk Characterization Phase

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Risk characterization is composed of two parts: risk estimation and risk description.
- Risk estimation involves the integration of the analysis of exposure and effects along with associated uncertainties. Professional judgment may be required in dealing with uncertainties.
- Risk description is a summary of risk estimation and the interpretation of the ecological significance of the estimated risks. Ecological significance considers the nature and magnitude of the effects, spatial and temporal patterns and effects, and potential for recovery.

Activities

- Estimate risk, evaluating effects and exposure data from the Analysis.
- Analyze and summarize risk, describing uncertainties and the ecological significance of the risk.

Risk Characterization Phase

The Risk Characterization Phase is where risk is estimated and described. In risk estimation, the exposure and effects analyses are integrated and an evaluation of risk is made (i.e., the likelihood that exposure to a stressor has resulted or will result in adverse effects). After risk estimation, the assessor determines the ecological significance of the risk. This includes the nature and magnitude of effects, spatial and temporal extent of effects, and potential for recovery. Finally, the risk is described with all assumptions and uncertainties clearly stated.

EPA has issued guidance on Risk Characterization that applies to ecological risk assessment as well as human health risk assessment. This guidance (Appendix E) calls on EPA to "disclose the scientific analyses, uncertainties, assumptions, and science policies which underlie our decisions as they are made throughout the risk assessment and risk management process." Risk Assessors play a fundamental role in this process.

RISK CHARACTERIZATION WORK SHEET #1

Information you will need for this work sheet is contained in:

Analysis IS#2	**Number of Exposed WormFree Granules After Band Application**
Analysis IS#3	**Representative Bird Species Likely to be Exposed to WormFree Based on Field Observations**
Analysis IS#4	**Summary of Bird Kill Incidents Due to Poisoning by Direct Consumption of WormFree Granules on Corn (1972-1987)**
Analysis IS#5	**Summary of Bird Kill Incidents Due to Secondary Poisoning From WormFree Granules on Corn (1983-1986)**
Analysis IS#6	**Laboratory Acute Oral Toxicity (LD_{50}) Values of WormFree**
Analysis IS#7	**Field Study of Bird Kills After Application of Granular WormFree to Corn**

Risk Characterization IS#1 The Quotient Method
Risk Characterization IS#2 LD_{50}/Ft^2 for Corn
Risk Characterization IS#3 FWS Consultation Under ESA
Risk Characterization IS#4 Ecological Significance

1. Assume the major pathway for exposure is ingestion of WormFree granules. Read Risk Characterization Information Sheet #1 on the Quotient Method, and evaluate the Hazard Quotient Ratios calculated for the birds specified in Risk Characterization Sheet #2.

2. Is your conclusion consistent with the other information you considered in your exposure and effects analysis?

3. What are the strengths and weaknesses of the different data showing that WormFree causes bird deaths?

RISK CHARACTERIZATION WORK SHEET #1 (Continued)

Risk Characterization

4. What ecological effects, other than bird deaths, would you expect from application of WormFree (other effects in birds, effects in other organisms)? What data do you have that supports those expectations?

5. Are the estimated risks ecologically significant? Consider your answers to the previous questions and Risk Characterization Information Sheets #3 and #4.

RISK CHARACTERIZATION WORK SHEET #1 (Continued)

Risk Characterization

6. Assume you are presenting this information to a Risk Manager. Write a brief paragraph on your findings. How do you document your conclusions, including your uncertainties?

7. Does your paragraph meet the values of transparency, clarity, consistency and reasonableness as outlined in Carol Browner's risk characterization memo (See Appendix E)?

RISK CHARACTERIZATION INFORMATION SHEET #1

The Quotient Method

A quotient method is used to calculate a numerical estimate of the likelihood that an ecotoxicological effect of concern might occur.
In general, the quotient method involves three steps:

1. Determine the toxicological level of concern (TLC) for the most sensitive species under investigation. This becomes the denominator in the calculation (e.g., LD_{50}, NOEC, LOEC).

2. Determine the Estimated Environmental Concentration (EEC) for the chemical. This becomes the numerator in the quotient calculation.

3. Calculate the Hazard Quotient ratio = $\frac{\text{Estimated Environmental Concentration (EEC)}}{\text{Toxicological Level of Concern}}$

Quotients equal to or greater than one represent a strong likelihood that an ecotoxicological effect of concern *will* occur.

Quotients considerably less than one represent a strong likelihood that an ecotoxicological effect of concern *will not* occur.

Quotients approaching one represent an uncertain risk. Usually additional data are needed to further characterize the risk.

The quotient method is simple and straightforward, is easy to comprehend and implement, and has relatively simple data needs. On the other hand, the quotient method has several limitations:

- It does not adequately account for effects of incremental dosages, indirect effects (e.g., food chain interactions), or other ecosystem effects (e.g., predator-prey relationships, community metabolism).

- It cannot compensate for differences between laboratory tests and field populations.

- It cannot quantify uncertainties or provide a known level of reliability.

RISK CHARACTERIZATION INFORMATION SHEET #2

Hazard Quotient Ratios For WormFree

Animal	Application Rate (lb AI/Acre)	Hazard Quotient Ratio*
American Goldfinch (Song bird)	1	0.9
Northern Bobwhite (Game bird)	1	1.1
Mallard (Waterfowl)	1	2.6

* Some of the factors involved in the Hazard Quotient Ratio are: the LD_{50}, body weight of bird, and ratio of Active Ingredient (AI) per granule.

RISK CHARACTERIZATION INFORMATION SHEET #3

FWS Consultation Under ESA

Because an endangered species, the Bald Eagle, was found dead, EPA requested a consultation from the U.S. Fish and Wildlife Service (FWS) on the registration of WormFree. Under Section 7 of the Endangered Species Act (ESA) EPA may request such assistance.

The FWS reviewed information from EPA, the pesticide manufacturers and formulators, and wildlife groups, as well as its own files. The FWS issued an opinion that the Bald Eagle is an "adversely affected species". This means that the species is likely to be impacted by use of the pesticide but their continued existence is not jeopardized beyond recovery.

RISK CHARACTERIZATION INFORMATION SHEET #4

Ecological Significance

Ecological significance pertains to the nature and magnitude of effects, spatial and temporal patterns of effects, and recovery potential.

The **nature** of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area are assessed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effects will depend on the ecological context. For example, a reduction in reproductive capability of a population would have greater effects on a whale population than on plankton (microscopic organisms living in the ocean) because whales take much longer to mature and produce fewer young over longer periods of time. Effects are of a significant magnitude if they cause interruption, alteration, or disturbance of major ecosystem processes such as primary production, consumption, or decomposition. Furthermore, effects may be significant if higher levels of biological organization are affected: 1) A physiological change becomes biologically significant if it affects a characteristic of the whole organism, such as survival or the ability to reproduce; 2) A change in the ability to reproduce among individuals becomes ecologically significant if it affects the size, productivity, or other characteristic of the population; and 3) A change in the size of a population becomes ecologically significant when it affects some characgteristic of the community or ecosystem.

Spatial and temporal patterns of effects consider whether effects occur on large scales, (e.g., acid rain), or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves, (e.g., ozone depletion effects on marine ecosystems).

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

DECISION MAKING

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Decision Making

Contents

Work Sheets (WS)

WS #1: Decision Considerations
WS #2: Decision

Information Sheets (IS)

IS #1: Pesticide Regulation
IS #2: Benefit and Alternative Methods and Chemical Analyses
IS #3: Public Concerns

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Summary of Decision Making Phase

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Making an informed management decision requires an understanding of the results of risk characterization, economic and socio-political considerations, and alternatives.
- Decisions involve factoring in uncertainty, trade-offs, and risks of alternatives.
- Enforceability and evaluation of decisions are issues that need to be addressed in decision making.
- Ecological risk decisions need to be documented to help make future decisions.

Activity

- Consider management options, followed by selection of a well documented final management decision.

Decision Making Phase

A number of factors are considered in decision making, including:

- The results of the risk assessment or risk characterization;
- Economic analyses;
- Socio-political concerns;
- Legal considerations (e.g., enforceability); and
- Options.

Usually, some of these factors play a larger role than others. Whichever decision is made there should be some documentation so that precedents can be established. Also, consideration should be given to monitoring the effectiveness of the decision so that better decisions can be made in the future.

DECISION MAKING WORK SHEET #1

Decision Considerations

Read Information Sheets #2 and #3, then discuss the four decision options associated with this scenario by completing the table below. Also, discuss the alternatives (substituting pesticides, crop rotation, scouting, education and any others). Table may be completed by using "+" and "-"; "+" = supports options, "-" does not support option.

WORMFREE ANALYSIS

DECISION FACTORS	DECISION OPTIONS				NON-REGULATORY OPTIONS			
	CANCEL REGISTRATION RELY ON NOWORM SUBSTITUTE	SUSPEND REGISTRATION RELY ON NOWORM SUBSTITUTE	MODIFY TERMS & CONDITIONS	CONTINUE WITHOUT MODIFICATIONS	A	B	C	D
ECOLOGICAL IMPACT - SPECIES AFFECTED - POPULATION IMPACTS								
ECONOMIC IMPACTS - CROP VALUE - COSTS OF USE OR PRODUCTION								
SOCIOPOLITICAL IMPACTS - PUBLIC COMMENT - CONGRESSIONAL COMMENT - MEDIA								

A = Crop Rotation
B = Scouting
C = Education
D = Other

DECISION MAKING WORK SHEET #2

DECISION

You have analyzed exposure and ecological effects and have derived an estimate of the ecological risk associated with the application of WormFree granules. Now, wearing your Risk Manager's hat, it is time to make a decision with regard to the registration of this pesticide and present it to the Assistant Administrator. Do you cancel registration, suspend registration, modify the terms and conditions of the registration, or continue registration without modification? Why?

Decision Made: ______________________________

Justification:

DECISION MAKING INFORMATION SHEET #1

Pesticide Regulation

There are **four primary methods** used by EPA's Office of Pesticide Programs to manage pesticides:

- **Registration**
- **Suspension**
- **Cancellation**
- **Modification**

Registration—designated **specific use** on a **specific site**; primary enforcement is the pesticide label.

If at any time EPA determines that the risk/benefit ratio is unacceptable, EPA may suspend, cancel, or modify the terms and conditions of registration.

Suspension—the use of all products containing the active ingredient are no longer allowed because it presents an imminent hazard to health or the environment. All remaining stocks are called in for disposal.

Cancellation—it can no longer be used for the specified purpose; existing stocks can be used.

Modification—changes are made to the specific use of the product; may include restricting use to certified applicators. These changes appear on product labels.

DECISION MAKING INFORMATION SHEET #2

Benefit and Alternative Methods and Chemical Analyses

Under FIFRA, EPA must weigh the risks of continued use of a pesticide against the benefits of that use. For agricultural uses, this usually involves estimating the economic costs associated with canceling the use—costs from any increased crop losses due to pest damage or from switching to more expensive alternatives. This Information Sheet contains a summary of some of the benefits of granular WormFree on corn.

Benefit Analysis for Granular WormFree Use on Field Corn

1. **Major Pests Controlled**

   Corn rootworms: Larvae feed on roots, which decreases yield.

2. **Extent of Usage**

   Usage of granular WormFree represents an estimated 60 to 70 percent of the field corn insecticide market.

   An alternative to WormFree, Noworm accounts for about 30 to 40 percent of the insecticide use on field corn.

3. **Economic Impact of Cancellation**

   EPA estimates that cancellation of granular WormFree on corn would have a short-run economic impact on farmers. It is estimated that the corn market would see a cost increase between $4.3 and $5.2 million per year, if the price of noworm is not affected. This is less than 0.05 percent of the average annual total value of field corn production ($15 billion). These estimated cost increases amount to $1.09-1.34 per acre of corn currently being treated with WormFree. This represents less than 1 percent of total per-acre cash expenses ($146-170/acre) of corn production.

   If the price of NoWorm increases 1 to 5 percent in response to cancellation of granular WormFree, cost impacts would be $7.3-23.2 million per year. No data are available to predict the likelihood of such price increases. No significant effects on corn yield or corn prices are expected.

DECISION MAKING INFORMATION SHEET #2 (Continued)

Benefit and Alternative Methods and Chemical Analyses

4. Alternative Methods

State and Federal extension service personnel recommend crop rotation and scouting as part of an integrated pest management strategy. These methods are not factored into quantitative estimates because of insufficient usage data.

Crop rotation

Crop rotation is the successive planting of different crops in the same field. Corn is often followed the next year by soybeans, alfalfa or small grains.

<u>Benefits</u>

- Less use of WormFree;
- Delays development of resistance to pests;
- More efficient control of weeds, insects, and diseases resulting in increased yields;
- Less soil erosion and more nitrogen fixation (therefore less use of fertilizers); and
- Fewer human health and ecological effects.

Scouting

Scouting is the inspection of a field for pests. It is used to determine whether pest populations have reached levels that warrant control and to help determine the appropriate method of control.

<u>Benefits</u>

- Efficient use of WormFree; and
- Potentially fewer human health and ecological effects.

<u>Cost</u>

- Labor costs higher because monitoring; however, may be offset by potentially less use of WormFree.

DECISION MAKING INFORMATION SHEET #2 (Continued): COMPARISON TO ALTERNATIVE CHEMICAL

Pesticide	Description	Ecological Effects	Cost
NoWorm	- granular - as effective as WormFree - highly mobile - may leach - persistent in the environment	- slightly less toxic to avian species than WormFree - very toxic to freshwater invertebrates - 6 incident reports on a number of aquatic species; 90,000 in one incident; incidents were after application and rainfall - studies showed effects on mallard eggs laid and set, viable embryos, and number of hatchlings; morphological changes in reproductive organs were observed - at lower doses mallard weight gain began to decrease - bobwhite quail studies at similar exposure levels produced no reproductive effects - no field studies on terrestrial organism toxicity (Note: doses used in these studies are at and slightly higher than exposure levels in the field)	- $.70/acre more than WormFree
WormFree	- highly mobile - potential to leach - persistent in the environment	- (your analysis here)	

DECISION MAKING INFORMATION SHEET #3

Public Concerns

There are many different viewpoints regarding the ecological risk of WormFree.

- **Producers and blenders** of WormFree have been conducting a media campaign to develop support for the continued use of the pesticide. Some of the information given to the media is misleading. It has raised concern among the general public regarding price increases and the safety of the food grown without WormFree. Representatives of the industry have been meeting with key Congressional members about this issue, stating they have proposals for major amendments to FIFRA.

- **Environmental groups** believe there is strong evidence to cancel the use of WormFree altogether and immediately. They have also been talking to appropriate Congressional committees to make their viewpoint known.

- The **national media** has run a few stories on this pesticide, especially in the central United States, where most corn is grown. The coverage has been sporadic, and inconclusive in most cases.

- The media coverage of this story in **Congressman McDonald's** district has been supportive of the continued use of the pesticide. One of the largest producers of the pesticide is located in that district, and the Congressman has spoken publicly and with the EPA Administrator in favor of continued use.

8. Superfund

8. SUPERFUND SITE

GROUP EXERCISE
Zap-A-Bug Old Warehouse Site

Contents

Case Study Background and Information Sheets

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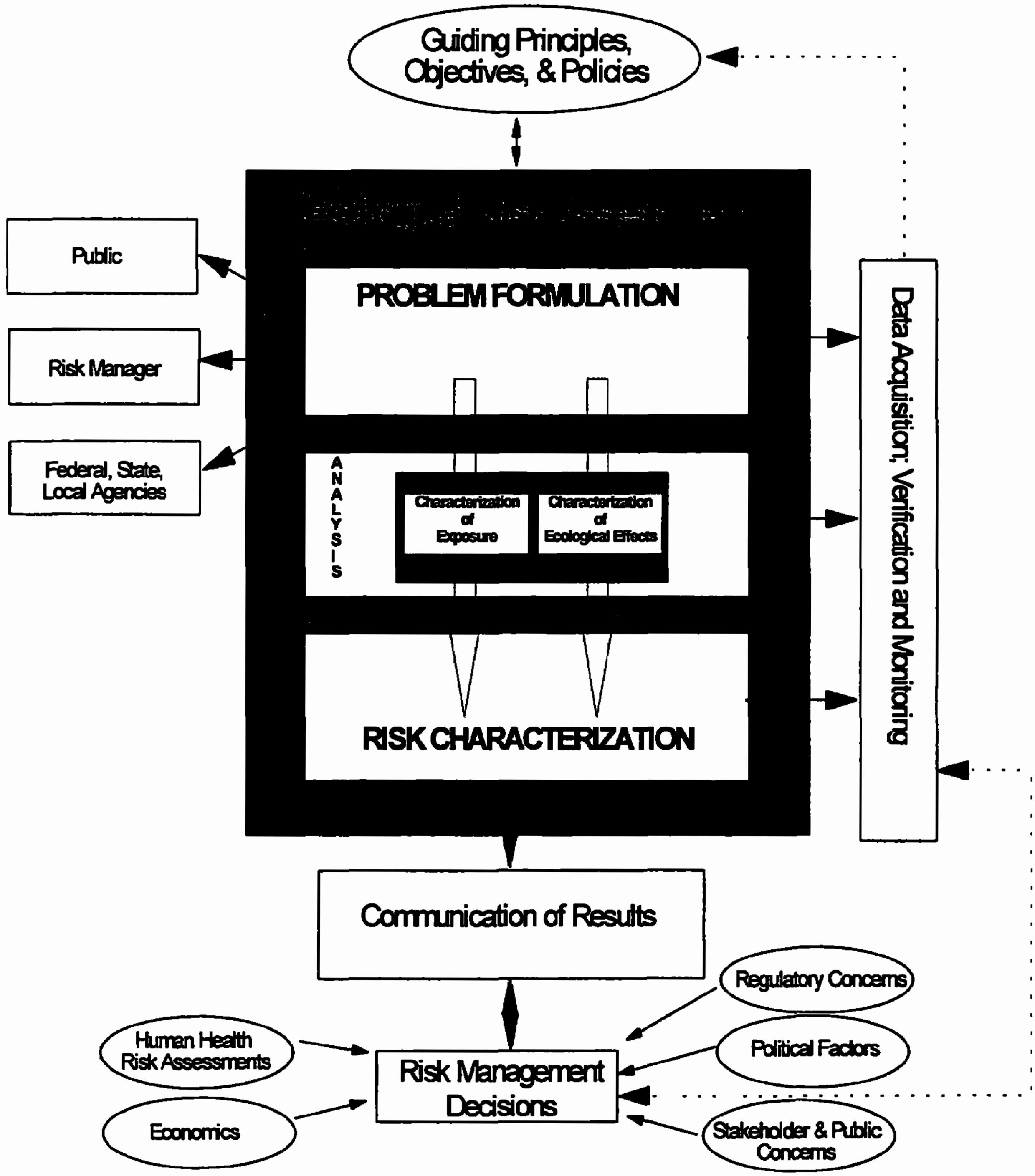
Guiding Principles, Objectives, & Policies
Public
Risk Manager
Federal, State, Local Agencies
PROBLEM FORMULATION
ANALYSIS
Characterization of Exposure
Characterization of Ecological Effects
RISK CHARACTERIZATION
Data Acquisition; Verification and Monitoring
Communication of Results
Regulatory Concerns
Human Health Risk Assessments
Political Factors
Risk Management Decisions
Economics
Stakeholder & Public Concerns

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OVERVIEW OF THE GROUP EXERCISES

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Overview of the Group Exercise

Summary of Group Exercise

In this exercise, you will conduct an ecological risk assessment on a fictitious site under the Superfund Program. At the conclusion of the exercise, you will have three options to consider with regard to remediation of the site: no action, limited àction (cleaning up or removing the contaminated "hot spot" from the site), or extensive remediation. Your group will make a final decision and communicate it.

Phases of the Group Exercise

The exercise will be conducted in four separate sessions, with a report-out at the conclusion of each phase. These phases will focus on:

1. Problem Formulation
2. Analysis
3. Risk Characterization
4. Decision Making

Materials in This Package

- *Work Sheets.* Work Sheets will guide you through the exercise. Each Work Sheet includes questions or problems for group discussion. Your group should proceed through the Work Sheets in the order they are presented.

- *Information Sheets.* Information Sheets present information on the case study needed for the exercise. This information includes the basic case study background as well as additional case information that will be needed for each of the sessions.

Group Exercise Process

- The Facilitator will gather participants into groups. Each group will choose a leader, a recorder, and one person to report-out the group's recommendations and conclusions.

- Your group is to assume two roles. For the first three phases, your group will complete a risk assessment and communicate results to the decision maker. For the last phase, Decision Making, your group will change roles and integrate the results of the risk assessment with other information needed to reach a management decision.

- Group members will collaborate to develop answers to questions presented on the Work Sheets. You will present your findings to the rest of the workshop participants during the discussion sessions.

Overview of the Group Exercise (Continued)

References

Maughan, J.T. 1993. *Ecological Assessment of Hazardous Waste Sites.* (Maughan 1993). Van Nostrand Reinhold, New York.

Suter, G.W., II. 1993. *Ecological Risk Assessment.* Lewis Publishers, Chelsea, Michigan.

USEPA. 1989. *Risk Assessment Guidance for Superfund Volume II, Environmental Evaluation Manual.* EPA/540/1-89/001. U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1992. *Framework for Ecological Risk Assessment.* EPA/630/R-92/001. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

USEPA. 1992. *A Review of Ecological Assessment Case Studies from a Risk Assessment Perspective.* EPA/630/R-92/005. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

BACKGROUND ON CASE STUDY

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Background on Case Study

Time Allotted

Approximately 30 minutes.

Location and Site Description

The Zap-A-Bug Pesticide Manufacturing Plant is located on the Lower Fiasco River, in a rural area 10 miles upstream of Robin City in County A (please refer to the Fiasco Valley Watershed Map, Figure 1). As shown in Figure 2, approximately two miles upstream of the plant is a closed area (i.e., Old Warehouse site) designated as a Superfund site.

The site and its vicinity include the following features:

- There is a **Bald Eagle nest** on a woody knoll north of the Superfund site.
- The former warehouse site is currently **surrounded by a chain-link fence** and has been **capped** with clean surface soil.
- The vegetation in the immediate vicinity of the site consists of **low grasslands** with little rise in elevation.
- The former warehouse site is located on a downward slope of a hill, downgradient of Lake Snafu. To the north of the plant, below the hydroelectric dam, there are several **corn fields** and **tobacco fields**.
- **Groundwater flows south** toward the Fiasco River with some eastern flow components.
- Upstream of the site are farms and a campground using private wells. The river is important for recreational and subsistence fishing.
- An **undisturbed area with a wetlands** is found across the river, upstream of the Superfund site, below the hydroelectric dam.

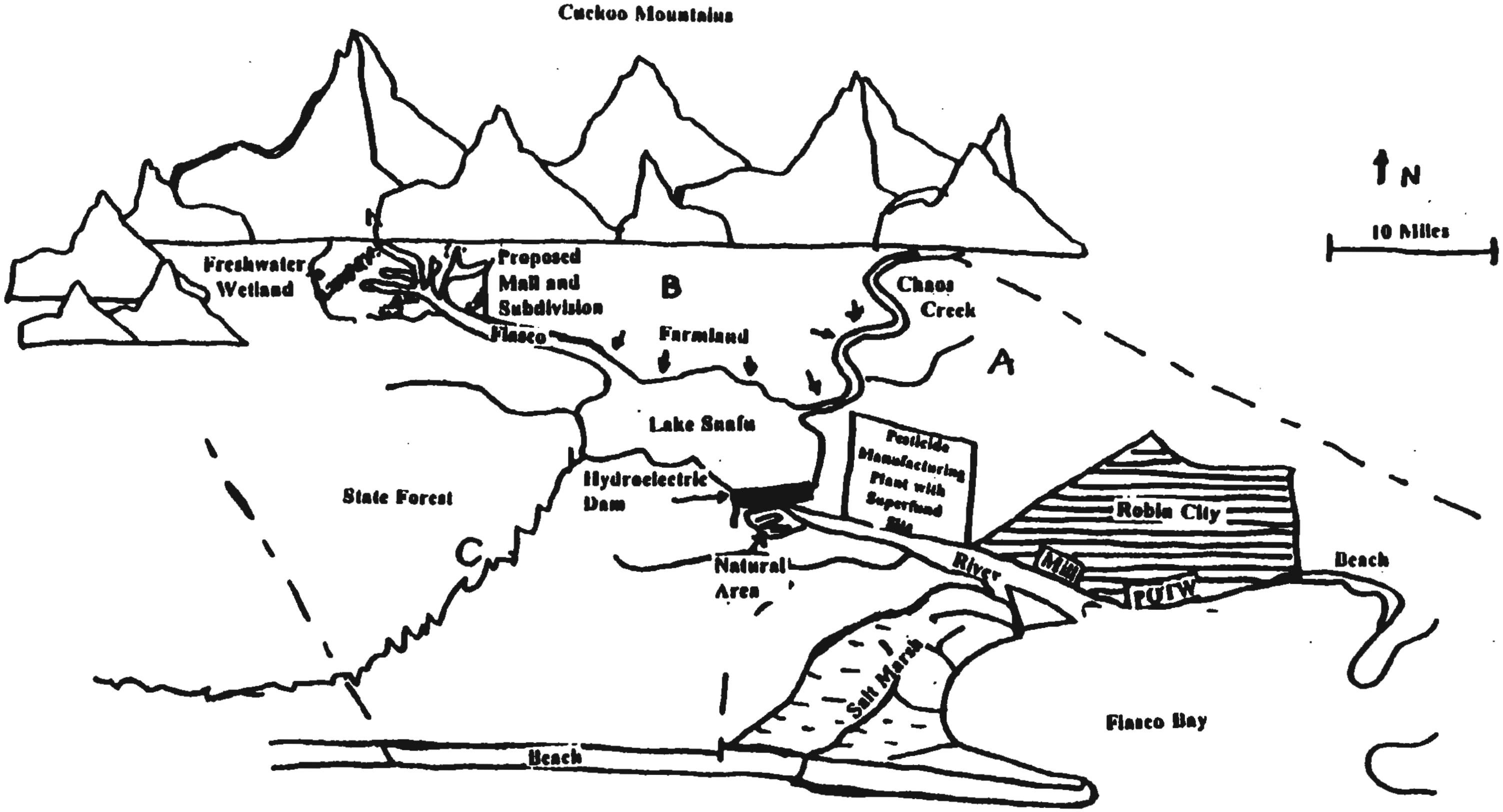

Figure 1. Flasco Valley Watershed

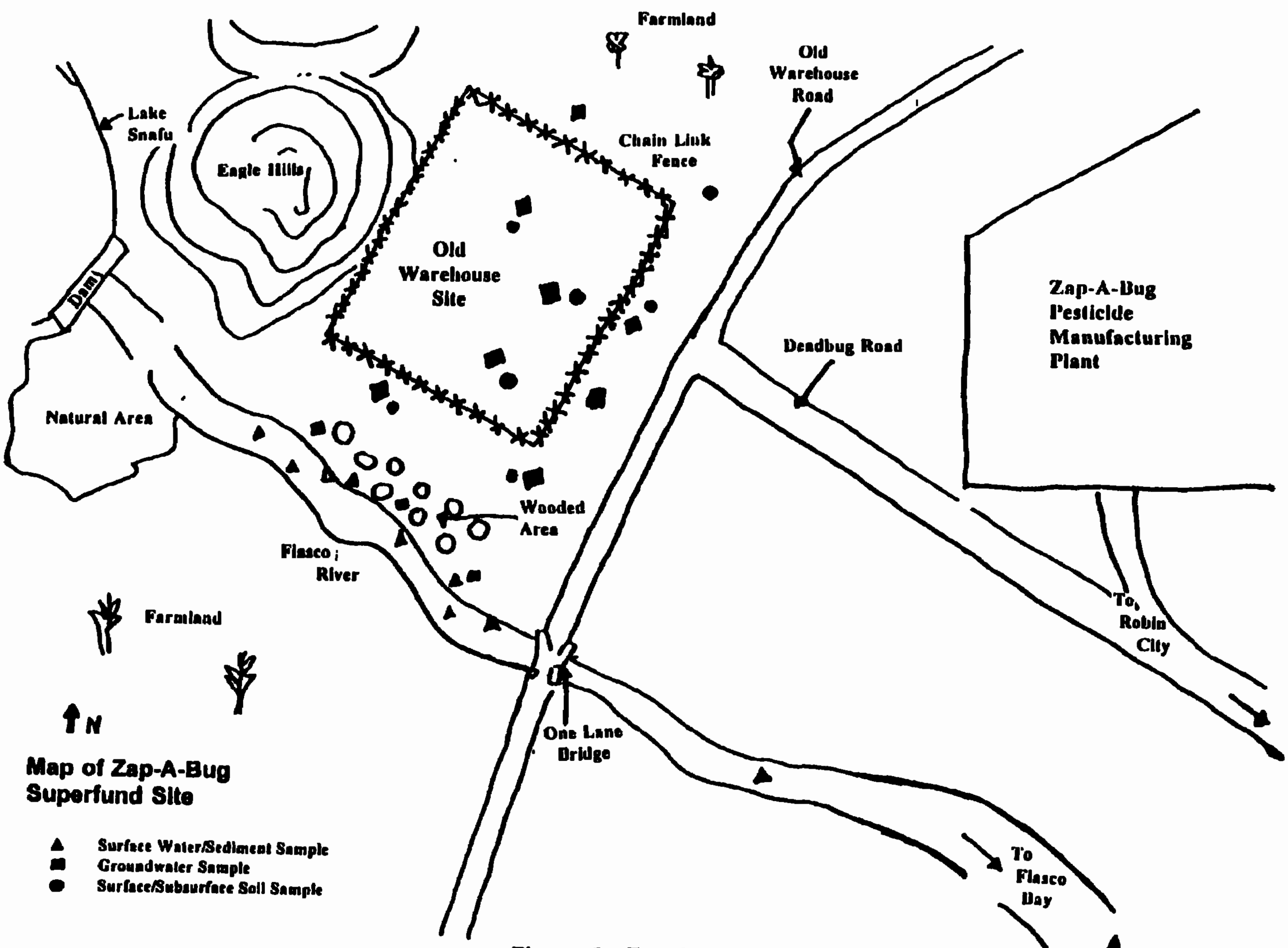

Figure 2. Zap-A-Bug Superfund Site

Background on Case Study (Continued)

Nature of the Problem

Chronology for Zap-A-Bug Old Warehouse Site

Date	Item
1970-1975	Warehouse is used to store waste products from Zap-A-Bug Pesticide Manufacturing Plant
1975	Warehouse demolished and wastes buried in drums under site of warehouse
1982	Site discovery—state senator alerts EPA
1985	Preliminary Assessment, Site Inspection, Hazard Ranking
1986	Site placed on National Priority List
Present	Remedial Investigation/Feasibility Study Record of Decision Remedial Design/Remedial Action

In 1982, a state senator who owned property approximately 5 miles from the former warehouse site brought the site to the attention of EPA. In 1985, the State conducted a Preliminary Assessment (PA). Based on the results of the PA and the potential for adverse impacts to the environment due to releases from the buried drums, the State requested that a Site Inspection (SI) be conducted with further sampling. **Sampling** included:

- Monitoring of **groundwater** in wells installed at the former warehouse site;
- Samples taken from **surface water** and **sediment from the river**, which have shown increased levels of contaminants used in pesticide manufacturing. Presumably, leaching of contaminants from the hazardous waste storage at the site to groundwater has occurred, and groundwater is a source to the surface water and sediment of the river; and
- Additional ecological information was collected from the State Department of Conservation.

The site has been included on the National Priority List based on its Hazard Ranking System score. An extensive Remedial Investigation (RI) is now in progress, which includes the baseline risk assessment report. The field investigation, laboratory analysis, and validation of surface water, sediment, soil, and groundwater data have been completed for the RI.

Several sensitive aquatic species may be adversely affected by the increased levels of certain contaminants. A description of known and potential wildlife habitats adapted from the Preliminary Site Assessment is included in an Information Sheet in the Problem Formulation section of this exercise. The site was also of

Background on Case Study (Continued)

concern to human health because of possible fish contamination. However, results from the SI demonstrated that levels of contaminants were below fish advisory levels for human consumption. The groundwater monitoring data showed that the groundwater was not contaminating the drinking water, which met EPA standards.

Stressor Characteristics

As part of the Remedial Investigation at the closed warehouse area of the Zap-A-Bug Plant, one chemical known to be toxic was detected at elevated levels in various media. Information Sheet #2, in the Problem Formulation Section, describes the chemical, toxicological information and its concentration in the Fiasco River and its sediments.

Pertinent EPA Program Offices and Other Agencies

The following government offices will play a role in the ecological assessment:

- EPA Headquarter's Office of Solid Waste and Emergency Response (OSWER);
- EPA Region 13;
- U.S. Fish and Wildlife Service;
- State Department of Environmental Regulation; and
- State Department of Conservation.

Statutory Requirements

The CERCLA program is under EPA's Office of Solid Waste and Emergency Response and, specifically, the Office of Emergency and Remedial Response (Superfund). CERCLA requires:

- Remediation of uncontrolled hazardous waste sites to protect both human health and the environment, meeting nine specific criteria for choosing remedies. (See Decision Making Information Sheet #1.)

- Ecological risk assessments to evaluate actual or potential effects of a hazardous waste site on ecological components. (It also requires human health risk assessments.)

- Project oversight by the Remedial Project Manager (RPM), including the ecological risk assessment.

Background on Case Study (Continued)

- Compliance with applicable or relevant and appropriate regulations (ARARs). The remedy must comply with laws such as the Clean Water Act, the Fish and Wildlife Coordination Act, and the Endangered Species Act, as well as state regulations on water quality standards and listed threatened or endangered species.

- Consultation with Natural Resource Trustees, which are those designated Federal and State agencies with responsibility for implementation of laws to manage and protect various natural resources. A Natural Resource Damage Assessment may be conducted simultaneously with the ecological risk assessment process.

NATURAL RESOURCE TRUSTEES

The Natural Resource Trustees are representatives of designated Federal and State agencies and Indian tribes who have duties relevant to the rehabilitation, restoration or replacement of natural resources injured or lost as a result of a release of oil or hazardous substances or wastes. This includes the Departments of Commerce (marine areas); Interior (minerals, migratory birds, endangered species, some water resources); and other land managers such as Agriculture, Energy, and Defense. States designate a trustee and cooperative lines among state agencies. Tribal chairmen act on behalf of land owned by each tribe.

The lead agency must notify the appropriate Trustee upon discovery of potential injury or loss, and consult with the Trustee in negotiations, investigations, decisions, or remediation. The Trustee may take the following actions upon learning there may be injury to or loss of a natural resource:

- **Conduct a preliminary survey to determine jurisdiction;**
- **Cooperate in investigations;**
- **Conduct damage assessments following approved protocols; and**
- **Develop and implement plans to rehabilitate, restore, replace or acquire equivalent resources.**

Definition and Purpose of the
Superfund Ecological Risk Assessment

In the Superfund Program, an ecological risk assessment is defined as a process for estimating the likelihood that adverse ecological effects (e.g., mortality, reductions in populations, or reproductive failure) will occur as a result of exposure to a hazardous substance released at a Superfund site.

The purposes of conducting the assessment are as follows:

- **Identify and characterize the current and potential threats to the environment from a hazardous substance release under the no-action alternative as part of the Remedial Investigation (RI).**
- **Evaluate the ecological impacts of alternative remediation strategies in support of the Feasibility Study (FS).**
- **Establish clean-up levels for the selected remedy that will protect those natural resources at risk as part of the FS and support the Record of Decision (ROD).**

The steps of the ecological risk assessment process presented in this workshop are based on the *Framework for Ecological Risk Assessment.* The *Framework* steps are compared below to the Ecological Assessment Process/Management Decision Points proposed by the Superfund program.

Comparison of Ecological Risk Assessments

Framework Process	Superfund Ecological Assessment Process
—	1. Preliminary Site Assessment
—	2. Preliminary Risk Calculation
Problem Formulation	3. Problem Formulation
Problem Formulation	4. Conceptual Model
Analysis	5. Site Assessment
Analysis	6. Site Investigation
Risk Characterization	7. Risk Calculation
Decision Making	8. Risk Management

Background on Case Study (Continued)

Endangered Species

The U.S. Fish and Wildlife Service (FWS), a branch of the Department of Interior, is the Federal agency responsible for administering the Endangered Species Act (ESA) of 1973 for most species. EPA must consult, either formally or informally, with the FWS if EPA determines that its action may affect a threatened or endangered (listed) species or its designated critical habitat. These EPA actions could include registration of a pesticide and any other decision authorized, funded, or implemented by EPA. Also, EPA must confer with the FWS if its action could affect a species or critical habitat that may be proposed for listing. If EPA determines that there will be no effect, consultation is not necessary.

Community Relations Requirements

Citizen interest was critical to the development of the CERCLA and continues to be a key element in the implementation of the law and the site study process. Regulations require a minimum level of community relations activities and encourage additional opportunities for citizen input and information as interest dictates. At designated points in the study process, certain activities must occur such as public meetings, fact sheets, and display ads in newspapers of local distribution. A local administrative record and information repository must also be made available early in the study process. These communications activities are established in a community relations plan for each site. This plan is based on interviews of citizens in the area of a site and are coordinated with the technical study plan. A spokesperson is designated by the lead agency, whether Federal or State, to serve as point of contact for all inquiries and to manage the community relations program for that site and that community.

When a preferred remedial option is designated by the lead agency, a proposed plan is issued in the form of an executive summary or fact sheet, ads are placed in local newspapers, a formal public comment period is held, and a public meeting is conducted to solicit input on the remedial options evaluated. A final Record of Decision (ROD) is issued with a Responsiveness Summary which documents the comments received and how the lead agency considered them in the final decision.

During the engineering design a number of communications activities may be conducted. However, an opportunity for a public meeting must be offered and a fact sheet on the engineering design must be issued before the design is completed. Again, during the actual implementation of the cleanup plan the community relations activities may vary depending on the level of interest and the specific issues which affect the community. This may include disruption of traffic patterns, dust control, emergency response preparation, evacuation plans, etc.

Background on Case Study (Continued)

Decision Options

At the conclusion of this exercise your team will decide among the following options:

- Take no remedial action;

- Limited remedial action, e.g., source removal (drums) and limited dredging of highly contaminated sediment in the recharge zone (the area in which the contaminated groundwater enters the river); or

- Extensive remedial action, e.g., extensive dredging of contaminated sediment downstream of the plant (e.g., recharge zone to 300 feet downstream of the recharge zone), source removal activities on-site, groundwater control measures (pump and treat) and long-term monitoring.

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PROBLEM FORMULATION

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Problem Formulation

Contents

Work Sheets (WS)

WS #1: Scoping and Selecting Exposure Pathways and Ecological Components by Developing a Conceptual Model
WS #2: Identifying and Selecting Assessment Endpoints and Public Involvement
WS #3: Identifying and Selecting Measurement Endpoints

Information Sheets (IS)

IS #1: Ecological Details from the Preliminary Site Assessment
IS #2: Details from the Preliminary Site Assessment: General Information on the Chemical Detected
IS #3: Case Study Update

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Summary of Problem Formulation Exercise

Time Allotted

Approximately 2 hours.

Key Concepts

- Problem formulation establishes the objectives and scope of the ecological risk assessment.

- The Risk Assessor should work with the Risk Manager to identify the objectives and scope of the risk assessment and the assessment endpoints. The Risk Assessor should be aware of the kinds of information needed by the Risk Manager to make a decision.

- An assessment endpoint is a formal expression of the environmental value to be protected and should be ecologically relevant, reflect policy goals and societal values, and be susceptible to the stressor.

- A measurement endpoint is a measurable response to a stressor that is related to the assessment endpoint.

- The public should be involved in selecting assessment endpoints and contributing information.

- The selection of assessment endpoints must be focused to meet the needs of the investigation while reflecting the availability of resources (personnel, financial, time).

Activities

- Identify and select ecological concerns.

- Develop a simple conceptual model.

- Identify and select assessment and measurement endpoints.

Task Overview

- Complete the Work Sheets in numerical order. Refer to the Information Sheets provided as needed.

- Choose a leader and spokesperson to make notes on the flip chart and present a summary of the group discussion. This may be two people or one person may conduct both tasks.

Problem Formulation Phase

The Problem Formulation Phase is where the planning for an ecological risk assessment takes place. The goals, breadth, and focus for the assessment are established in this phase, taking into account regulatory, policy, and public concerns. The Risk Manager and Risk Assessor work together to identify the ecological concerns or effects that are expected or have resulted from a particular activity or pollutant regulated by EPA (e.g., Superfund clean-up, RCRA corrective action, pesticide use, new chemical registration, filling wetlands, or discharging pollutants into waterways).

Public input at this stage is important because the public often has concerns and knowledge that will improve the assessment. Also, public input is often required by law. In addition to determining what to assess, decisions are made as to how to assess (i.e., literature search for information, measurements in the laboratory or field, etc.). Factors such as time, cost, and cooperation from other parties are considered when determining how to assess the problem.

Following are some concepts, terms, and tools useful in planning an ecological risk assessment:

Stressors

Stressors are the pollutants or activities that cause the ecological concern or effect.

Generally, the *Framework* classifies stressors as being chemical, physical, or biological. Examples include:

- Chemical-toxics, nutrients (nitrates in water);
- Physical-dredging or filling in waterways or wetlands, diverting water flow in a river by constructing a diversion or dam; and
- Biological-introducing exotic organisms.

Exposure Routes or Pathways

It is important to trace exposure routes or pathways of a stressor to determine all the possible components of the ecosystem that may be affected. Considerations include:

- Mobility of a stressor;
- Uptake of a chemical by plants and animals;

Problem Formulation Phase (Continued)

Exposure Routes or Pathways (Continued)

- Transformation (chemicals may degrade in the environment from exposure to light, or react with water or other chemicals to form substances that are non-toxic, less toxic, or more toxic than the original chemical); and
- Competition (biological stressors).

For physical stressors, the exposure may be immediately obvious (i.e., removing or destroying ecosystems by building a structure, dredging, or removing water for agriculture or drinking water supplies). The effects of physical stressors may be far-ranging, e.g., removal or diversion of water alters habitats downstream (bays become saltier, adversely affecting bay fish nurseries which require a mixture of fresh and salt water).

Ecological Effects

Ecological effects are the harmful responses of the ecosystem and its components to the exposure to stressors. Some examples include death, reproductive failure, decline in growth rate, habitat loss, etc.

Conceptual Models

Conceptual models are helpful in fully characterizing the ecological effects associated with stressors. These models may take the form of sketches of the ecosystem at risk (cross-section or plan view) with arrows illustrating routes of exposure, or they may be abstract in form with ecosystem components and stressors in boxes with arrows showing relationships between them.

Assessment Endpoints

The *Framework* uses the term assessment endpoint to identify the ecological concern(s) that will be the focus of the assessment. Criteria used to select assessment endpoints include:

- Sensitivity to stressors of concern;
- Ecological relevance; and
- Relevance to policy goals and societal values.

The assessment endpoint needs to be both affected by and sensitive to the stressor(s). Ecological relevance means that the assessment endpoint is important to the function of the ecosystem. For example, lake trout play an important role in maintaining the balance of aquatic ecosystems. However, the introduction of carp has disrupted the balance of aquatic ecosystems.

Problem Formulation Phase (Continued)

Assessment Endpoints (Continued)

Assessment endpoints also should reflect policy goals (e.g., protect endangered species and no net loss of wetlands). Societal values helped form the basis for these policies when environmental laws were enacted. However, policy or management goals (e.g., protect endangered species, maintain recreational fisheries) are not assessment endpoints. Assessment endpoints must be measurable.

Examples of assessment endpoints include: sustainably reproducing populations of trout species; maintenance of populations of aquatic vegetation that are supportive of fish and invertebrates; maintenance of reproductively successful songbird populations, etc. The more specific the assessment endpoint the better, (e.g., loss of no endangered bats).

Measurement Endpoint

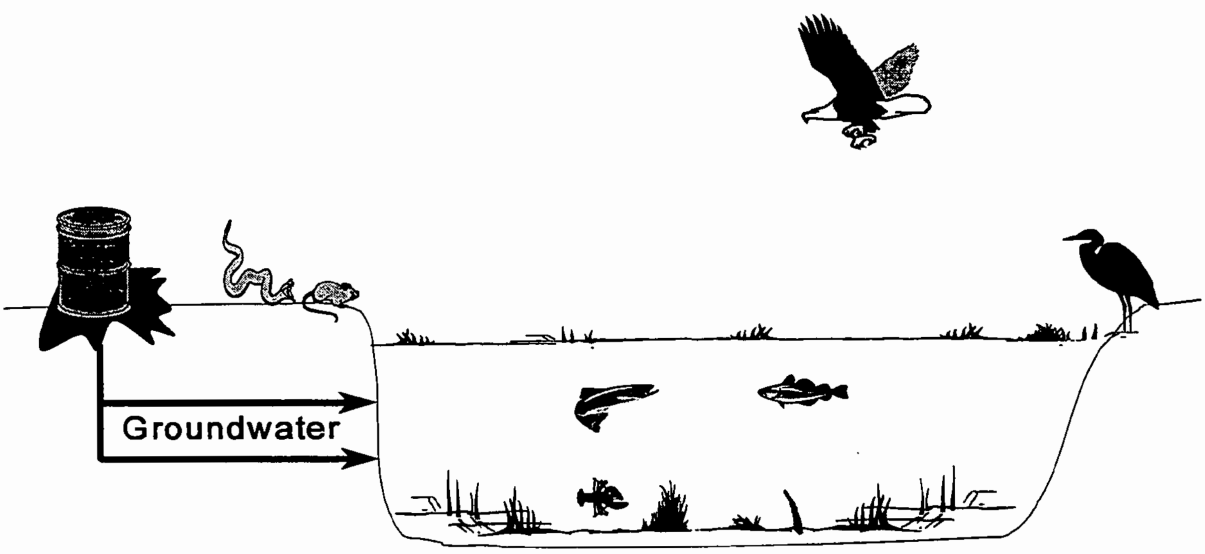
Measurement endpoint is another term used in the *Framework* referring to how we determine exposure and effects to an assessment endpoint. Examples of what to measure include concentration of a chemical in water and animal tissue, number of offspring, deformities, mortality, acres of wetlands removed, modeling impacts to a population, etc.

PROBLEM FORMULATION WORK SHEET #1

Scoping and Selecting Exposure Pathways and Ecological Components By Developing A Conceptual Model

Data from the site inspection (monitoring of surface soil, subsurface soil, groundwater, surface water, and sediment) show elevated levels of the contaminant in groundwater, surface water, and sediment (Information Sheet #2).

Based on the Case Study Information Sheets on wildlife, their habitats and feeding characteristics, and the chemical detected (Information Sheet # 1 and # 2), what are the ecological components potentially affected by the Superfund site? Use the diagram below to answer this question by sketching the relationships among the stressor, exposure routes, and ecological components.



PROBLEM FORMULATION WORK SHEET #2

Identifying and Selecting Assessment Endpoints and Public Involvement

1. With the ecological components on Work Sheet #1 develop 3-4 assessment endpoints.

Ecological Components	Assessment Endpoints

2. How can public input contribute to selection of assessment endpoints? See Problem Formulation Information Sheet #3.

PROBLEM FORMULATION WORK SHEET #3

Identifying and Selecting Measurement Endpoints

1. Prepare a list of measurement endpoints for the 3-4 assessment endpoints.

Assessment Endpoints	Measurement Endpoints

2. What types of activities would be required to obtain the selected measurement endpoints? What are the real world constraints on an ecological risk assessment, and how could these constraints affect your ability to carry out these activities?

PROBLEM FORMULATION INFORMATION SHEET #1

Ecological Details from the Preliminary Site Assessment

Field surveys of the site indicated a variety of wildlife species present in the vicinity of the site

Species	Habitat and Feeding Characteristics
Avian Species	
▸ Bald Eagle[1]	▸ The Bald Eagle feeds primarily on fish; it is at the top of the food chain. It is a year-round resident.
▸ Great Blue Heron	▸ The Great Blue Heron nests in rookeries in marsh/upland areas. It feeds on fish, crab, clams, frogs, snakes and insects. ▸ The Great Blue Heron feeds more locally than does the Bald Eagle
▸ Green-backed Heron	
▸ Other wading birds	
▸ Kingfishers	
▸ Passerines (songbirds)	▸ Songbirds migrate thousands of miles each year.
Reptiles and Amphibians	
▸ Cottonmouth snake	▸ The snake eats fish and mice
▸ Various frogs	
▸ Various salamanders	
Aquatic Species	
▸ Rockfish	▸ This is an important spawning area for rockfish They consume a variety of fish and invertebrates
▸ Trout	▸ Feed on small fish and invertebrates
▸ Perch	▸ Feed on small fish and invertebrates.
▸ Catfish	▸ Bottom dwellers feeding on dead and decaying organisms.
▸ Insects	▸ Feed on algae (microscopic plants) and decomposing organic material
▸ Crabs	▸ Bottom dwellers feeding on small fish and shellfish and on dead or decaying organisms
▸ Clams	▸ Bottom dwellers feeding on material suspended in the water.
Mammalian Species	
▸ River otters	▸ Otters consume bird eggs, fish, bottom-dwelling (benthic) invertebrates and small mammals They live in burrowed-out logs in upland areas or in grassy dens.
Vegetation	
▸ Pond Weed	▸ Both plants serve as valuable habitat for fish and as food for birds.
▸ Widgeon Grass	

[1] The Bald Eagle is federally listed as a threatened species, it remains a state-listed endangered species

PROBLEM FORMULATION INFORMATION SHEET #2

Details from the Preliminary Site Assessment: General Information on the Chemical Detected

OrganiX is the compound found to be the chemical of concern, or a toxic chemical likely to cause ecological problems. It is a polycyclic aromatic hydrocarbon compound which is **persistent** (not breaking down into its elements readily).

During the Site Inspection elevated levels of OrganiX were found in surface water and sediments. The maximum amount found at a sampling point was 0.0100 mg/L in surface water and 14.0 mg/kg in sediments. These levels were higher than the State criteria: 0.0019 mg/L for ambient water quality and 7.0 mg/kg for sediments.

A literature search has revealed that:

- Data are available from a study of a recent accidental spill of OrganiX. Residues of OrganiX were discovered in the liver, blood, intestinal tract, and reproductive organ tissue of dead birds at the spill site. **Neural transmitter chemicals** were found **at reduced levels** and **sex organs are of decreased size**. This chemical is believed to cause **shell thinning**, reducing hatching success.

- The same study found submerged **aquatic vegetation uptakes OrganiX readily.** Also, chronic exposure to OrganiX has led to **decreased aquatic vegetation productivity**. This has resulted in a loss of habitat for fish at the spill site.

- Several aquatic species are sensitive to chronic levels of OrganiX, including rainbow trout which show adverse early **life cycle effects** (such as poor gill/fin development, stunted growth, poor development of the reproductive system) in laboratory tests at 0.22 ug/L.

- Laboratory studies have shown that **amphipod (benthic invertebrate*) mortality** occurs at 9.7 to 186 mg/kg OrganiX in sediment.

* **Benthic Invertebrate** = Animals such as worms, clams, insects, lacking a backbone or spinal column, living in or on the bottom of aquatic environments.

PROBLEM FORMULATION INFORMATION SHEET #3

Case Study Update

Citizens' Groups Involved

Citizen interviews were conducted to identify the issues and level of interest held by groups or individuals in the community surrounding the Zap-A-Bug Warehouse sites. A summary of the results of the interviews appears below.

- The Zap-A-Bug Plant employs a significant number of workers from the area who could face losing their jobs if the plant (designated as the Potentially Responsible Party (PRP)) is required to put huge sums into remediation of the site.

- Other parties are interested in the tourism business including recreational fishing and boating. They would like to see the river kept clean, but want low-profile decisions made to avoid frightening potential tourists.

- Farmers are also concerned about the site and want assurance that their land and water supply are free from contamination.

- Landowners and homeowners in the area are concerned about the potential for a decrease in property value in the vicinity of the site.

- An environmental organization called Fix the Fiasco sees the Zap-A-Bug Plant as a major threat to wildlife in the area and to the river itself. They are actively speaking to the media about these issues and are often at odds with the local farming industry.

- A bird count conducted by the local Audubon chapter provided data on avian species found in the area as well as how the numbers have fluctuated over the years.

- A professor at the State College—Robin City has been conducting various wildlife studies in the area over the last 25 years, before the drums were placed on the site. He has provided information on species and habitat changes. He has also identified an invertebrate which is key to the food chain in the wetland/river area near the site. This invertebrate is a primary food source for fish which have important recreational and commercial value. Populations of this invertebrate have been decreasing over the years.

ANALYSIS

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Analysis

Contents

Work Sheets (WS)

Information Sheets (IS)

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Summary of Analysis Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- The major components of the Analysis Phase are characterization of exposure and characterization of ecological effects.

- Exposure analysis requires knowledge of: (1) stressor characteristics (physical, chemical and biological) in environmental media, (2) the probability that ecological components come into direct or indirect contact with the stressor, and (3) the timing of exposure to a stressor in relation to biological cycles.

- Both direct and indirect ecological effects should be addressed.

- Measurement endpoints must be related to assessment endpoints, and this often involves extrapolation from measured individual effects to estimated population and community level effects.

- Risk assessment requires varying degrees of professional judgment in dealing with uncertainties.

Activities

- Analyze exposure routes and pathways, consider stressor characteristics, and identify ecological components of concern.

- Analyze direct and indirect ecological effects.

- Identify uncertainties associated with the analysis phase.

Analysis Phase

The Analysis Phase is where both the exposure and effects of stressor(s) on the assessment endpoints are determined. This phase involves collecting and analyzing data in the literature, actual measurements in the laboratory or field, and modeling. As with any analytical work, there are uncertainties in the data and in interpreting data. These uncertainties should be documented, carried through the assessment, and presented as part of the results to the Risk Manager. Professional judgement is often a component of ecological assessments, and should be clearly identified when the results are presented to the Risk Manager. Similarly, any extrapolations (e.g., from individual to population to community, from laboratory to the field, or from one place to another) should be identified as one of the uncertainties.

Exposure Analysis

It is important to know how stressors behave in the environment, i.e., how solar radiation, water, sediments, soil, air, and the living components affect the movement and form stressors take in the environment. For example, non-affected organisms may metabolize toxic chemicals to non-toxic compounds. Both direct and indirect exposure should be analyzed. An organism may become exposed to a toxic chemical by eating a contaminated organism rather than by direct exposure (consider predator species). Temporal and spatial distribution of a stressor is important. The stressor might affect a certain life stage or the entire life cycle of an organism. The extent of exposure to a stressor could be localized or affect an entire region or large ecosystem.

Effects Analysis

Both direct and indirect effects should be analyzed. Examples of indirect effects are when organisms affected by a stressor are prone to disease, easier targets of prey species, and less competitive.

ANALYSIS WORK SHEET #1

Analysis of Exposure

HERON CHOSEN AS SURROGATE SPECIES

There is great concern about the welfare of the Bald Eagle as a threatened/endangered species. However, because it is rare it may be a violation of the Endangered Species Act to experiment or manipulate or harass it in an ecological assessment. After consultation with the U.S. Fish and Wildlife Service and the State Department of Conservation, the Great Blue Heron was chosen as a surrogate species for the ecological risk assessment for the Zap-A-Bug Warehouse Superfund site.

The Great Blue Heron is at a similar place in the food chain as the Bald Eagle and is more abundant. It feeds on more local resources, having a smaller geographic range than the Bald Eagle. Both the Great Blue Heron and Bald Eagle eat fish. Using the Great Blue Heron as an indicator species leaves undisturbed the few Bald Eagles in the area while still obtaining information critical to assessing and improving their habitat.

1. To which media are herons exposed? Why? Refer to Problem Formulation Information Sheet #1 and your conceptual model from the Problem Formulation Exercise.

2. What is the exposure pathway for herons (i.e., the way the chemical enters the organism)?

ANALYSIS WORK SHEET #1 (Continued)

Analysis of Exposure

3. What factors should be considered in determining the dose of a contaminant to which a heron is exposed? Refer to Analysis Information Sheet #1, "Determining Dose" to answer this question. What are some of the uncertainties and assumptions inherent in each approach?

   Factors to Determine Dose:

   Uncertainties and Assumptions:

ANALYSIS WORK SHEET #2

Analysis of Ecological Effects

TOXICITY REFERENCE VALUES

To evaluate the measured or calculated dose of contaminants to herons at the site, you need to know a "safe" dose for herons (using either NOEL or LOEL) to which to compare your heron dose. These "safe" level estimates are called toxicity reference values.

1. What are some of the uncertainties associated with the Toxicity Reference Value for herons presented in the Analysis Information Sheet #2?

2. Based on the information provided on the Reference site, and on the Fiasco River near the Superfund site in Analysis Information Sheet #3, what can one conclude about the ecological effects of the Superfund site? What other information would be helpful in this analysis? How does this assist in characterizing the risk from the site?

ANALYSIS INFORMATION SHEET #1

Determining Dose for Herons

The following approaches to determining a dose of a chemical consider the exposure of herons to surface water contamination via ingestion of potentially contaminated fish at the Zap-A-Bug Superfund site. For purposes of this exercise, the pathway of "surface water—to fish—to herons" will be the focus of discussion.

A dose equation would be used to model exposures to herons in Approaches 1 and 2. A typical dose equation would consider 1) the concentration of OrganiX in surface water; 2) a bioconcentration factor or BCF; 3) average body weight of the heron; 4) amount of fish consumed per day; and 5) a factor for the percent of contaminated fish the heron consumes per day.

(1) ***Modeling exposures to herons using laboratory derived fish BCFs***

Laboratory fish BCFs would be derived by exposing fish to OrganiX in tanks with either free flowing or static water conditions over a period of time.

(2) ***Modeling exposures to herons using fish BCFs derived from field data***

For this site, you must decide which fish species to sample and how many samples to collect. The cost is $3,000 per sample. Consider also the time and season for the sampling. Fish tissue data is available through literature searches and from the professor at the State College - Robin City.

Some of the assumptions associated with Approaches (1) & (2) inlcude the following:

- **average body weight estimated from the literature;**
- **amount of fish consumed per day for average body weight heron estimated form literature; and**
- **factor for percent contaminated fish consumed per day would include estimated feeding range for herons.**

(3) ***Measuring exposures to herons using residue analysis.***

A direct approach to assessing impacts on herons would be: (a) to collect birds from the field for blood samples or tissue residue analysis to determine whether site chemicals are bioaccumulating and/or (b) to analyze eggshells of nesting birds. Either approach will cost $5,000 per sample. This option would rarely be used for a Superfund ecological risk assessment because of time and budget constraints as well as U.S. Fish and Wildlife and state agency regulations.

ANALYSIS INFORMATION SHEET #2

Results of Dose Estimates For Herons

Chemical	Estimated Dose Using Fish BCF from Lab Data (mg/kg/day)	Estimated Dose Using Fish BCF from Field Data (mg/kg/day)	Estimated Dose Using Residue in Heron Tissue (mg/kg/day)
OrganiX	2.0	1.0	0.2

Bioconcentration Factor (BCF) = A unitless value equal to the concentration of chemical in the tissues of an organism divided by the concentration of that chemical in the medium to which it was exposed.

Toxicity Reference Value for Herons

0.02 mg/kg/day

Toxicity Reference Value (TRV) = TRV is either a No-Observed-Effect-Level (NOEL), or Lowest-Observed-Effect-Level (LOEL), and is derived from laboratory studies.

ANALYSIS INFORMATION SHEET #3

Information on Reference Site and Fiasco River Near the Superfund Site

Reference Site

Just below the hydroelectric dam, along the west bank of the river in County A, lies a natural area which had been undisturbed for decades. It was decided that this area would serve as a good reference site, providing information on background conditions for the birds, fish, vegetation, invertebrates and sediments to compare with the Superfund site. This area is included in the ongoing studies by the professor at State College—Robin City and Audubon Society.

The Professor has studied the area along the river south of the natural area to the bay. Also, the State Departments of Environmental Regulation and Conservation and the Audubon Society have collected data in the same area.

Reference Site Data:

Submerged Aquatic Vegetation (SAV)

SAV is comprised of pond weed and widgeon grass. The professor conducted extensive studies of SAV in the Fiasco river area and published several papers based upon these studies. Grass beds were found to be highly productive based upon oxygen production, carbon-14 uptake, and growth measurement data. Similarly, plant biomass per square meter was considered to be very high compared to other locations in the region. The SAV beds are very dense and lush occupying expansive areas.

Fish Populations

The State Department of Conservation monitors fish populations at fixed stations on the river from just below the dam in the reference site area to the mouth of the Fiasco Bay. Species for which there is an abundance of data include rockfish, trout, perch, catfish, and eel. It is difficult to attribute any changes in fish populations to the superfund site due to the mobility of the fish. However, there are overall trends in the data including, 1) rockfish populations are rebounding from a decline over the last 10 years due to fishing restrictions, 2) trout and perch populations have declined slightly over the last 4 years due to fishing pressure, 3) catfish populations have increased over the last 3 years, and 4) eel populations have been fairly stable over the last 10 years.

Analysis Information Sheet #3 (Continued)

Bird Populations

The Audubon Society regularly collects data on bird populations along the river corridor. Audubon data show that populations of the great blue heron, green-backed heron, and kingfishers resident in the natural area were fairly stable (based upon bird counts and number of eggs produced) over the last several years.

Wildlife Populations

Over the last 20 years, the State Department of Conservation collected data on river otters inhabiting the Fiasco River. The river otter population resident at the natural area has been thriving with recent increases in numbers of adults.

River Data:

Submerged Aquatic Vegetation (SAV)

SAV distribution near the superfund site is patchy with evidence of dying widgeon grass blades. Productivity levels are lower than similar SAV beds in the reference site area. These data are from the professor's study sites.

Invertebrate Populations

The professor is an expert in the study of amphipods, or small crustaceans living on the bottom. Amphipods are an important food source for fish. The professor has extensive data over the years for amphipods inhabiting the Fiasco River. Recently, he has been concerned about a sharp decrease in the amphipod population near the superfund site. To date, he has not discovered the reason for this decline.

Bird Populations

The Audubon society monitors the bald eagle nest site and also collects data on herons and kingfishers along the river near the superfund site. Their data show that over the last few years the bald eagles produced some eggs with thinner shells which resulted in lower offspring survival. Audubon data indicate slight decreases in the resident great blue and green-backed heron populations and declining kingfisher populations.

Wildlife Populations

The State Department of Conservation noticed a sharp decrease in the river otter population near the superfund site over the last few years. In addition, last year two dead otters were found along the shore just down river of the superfund site. The cause of death was inconclusive because the animals were too decomposed when they were found.

Analysis Information Sheet #3 (Continued)

Sediment Quality, Fish Pathology, and Fish Tissue Survey

Recent concerns over contamination in the lower Fiasco River and Bay led the State Department of Regulation to institute a monitoring program. Monitoring stations extend from just below the dam to the mouth of the bay. The stations below the dam and above the superfund site were not considered to be contaminated, but were included as reference sites. The five-year data set shows that for the stations near the superfund site there are incidences of lesions on catfish, levels of OrganiX in sediment exceeding the state standard, and fish tissue levels below the state advisory level. The stations upriver of the superfund site showed levels of OrganiX in sediments well below the state standard, no evidence of fish lesions, and fish tissue levels below the state advisory level.

RISK CHARACTERIZATION

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Risk Characterization

Contents

Work Sheets (WS)

Information Sheets (IS)

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Summary of Risk Characterization Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Risk characterization is composed of two parts: risk estimation and risk description.

- Risk estimation involves the integration of the analysis of the exposure and effects along with associated uncertainties. Professional judgment may be required in dealing with uncertainties.

- Risk description is a summary of risk estimation and the interpretation of the ecological significance of the estimated risks. Ecological significance considers the nature and magnitude of the effects, spatial and temporal patterns and the effects and potential for recovery.

Activities

- Estimate risk, evaluating effects and exposure data from the analysis.

- Analyze and summarize risk, describing uncertainties and the ecological significance of the risk.

Risk Characterization Phase

The Risk Characterization Phase is where risk is estimated and described. In risk estimation, the exposure and effects analyses are integrated, and an evaluation of risk is made (i.e., the likelihood that exposure to a stressor has resulted or will result in adverse effects). After risk estimation, the assessor determines the ecological significance of the risk. This includes the nature and magnitude of effects, spatial and temporal extent of effects, and potential for recovery. Finally, the risk is described with all assumptions and uncertainties clearly stated.

EPA has issued guidance on risk characterization that applies to ecological risk assessment as well as human health risk assessment. This guidance, found in Appendix E under the title "Risk Policies", calls on EPA to "disclose the scientific analyses, uncertainties, assumptions, and science policies which underlie our decisions as they are made throughout the risk assessment and risk management process." Risk assessors play a fundamental role in this process.

RISK CHARACTERIZATION WORK SHEET #1

Risk Characterization

The Quotient Method

The Quotient Method is a quantitative predictive approach to evaluate risk based on a comparison between an expected environmental concentration (EEC) or dose, and a toxicological benchmark (such as LC_{50}, LOEL, etc.). It determines whether there is a high probability of concern with a particular chemical concentration. It is a tool for ranking a series of contaminant sources by their potential for producing adverse environmental effects.

The Quotient Method calculates a ratio using the Toxicological Level of Concern as the denominator. The numerator is the Estimated Environmental Concentration (EEC) or dose for the chemical. A number equal to or greater than one represents a strong likelihood that an ecotoxicological effect of concern will occur. If the number approaches one, the risk is uncertain and additional data are needed to further characterize the risk. A number considerably less than one represents a strong likelihood that an ecotoxicological effect of concern will not occur.

The Quotient Method has several limitations, including:

- **It does not adequately account for effects of incremental dosages, indirect effects (e.g., food chain interactions), or other ecosystem effects (e.g., predator-prey relationships).**
- **It cannot compensate for differences between laboratory tests and field populations.**
- **It does not account for multiple chemical exposures.**
- **It cannot quantify uncertainties or provide a known level of reliability.**

1. Make a risk estimate for OrganiX.

   To prepare this estimate calculate a ratio of the dose to the toxicity reference value from Analysis Information Sheet #2, "Results of Dose Estimates Compared with Toxicity Reference Value for Herons." Use the dose derived from heron tissue.

   Exposed Dose:

   Toxicity Reference Value:

RISK CHARACTERIZATION WORK SHEET #1 (Continued)

Risk Characterization

2. Why is risk indicated?

3. Describe the uncertainties.

4. Compare the Superfund site to the reference site (Analysis Information Sheet #3). Is risk still indicated? How does looking at all the available data (including the FWS consultation) affect the assessment of risk above and beyond the mathematical ratio obtained from the Quotient Method?

FWS CONSULTATION UNDER ESA

Bald Eagles inhabit the area and could be potentially exposed to chemicals from the Superfund site. Therefore, EPA requested a consultation from the U.S. Fish and Wildlife Service (FWS) on the impacts of the Superfund site to listed species.

The FWS reviewed information from EPA, the State, the potentially responsible party, and local wildlife groups, as well as its own files. The FWS issued an opinion that the Bald Eagle is an "adversely affected species". This means that the species is likely to be impacted by chemicals from the Superfund site, but their continued existence is not jeopardized beyond recovery.

RISK CHARACTERIZATION WORK SHEET #1 (Continued)

Risk Characterization

5. Are the risks ecologically significant? Refer to Risk Characterization Information Sheet #1—Ecological Significance.

RISK CHARACTERIZATION WORK SHEET #1 (Continued)

Risk Characterization

6. Assume you are presenting this information to a Risk Manager. Write a brief paragraph on your findings. How do you document your conclusions including your uncertainties? Be sure that your paragraph is consistent with the values of clarity, consistency, and reasonableness as outlined in Carol Browner's risk characterization memo (Appendix E).

RISK CHARACTERIZATION INFORMATION SHEET #1

Ecological Significance

Ecological significance pertains to the nature and magnitude of effects, spatial and temporal patterns of effects, and recovery potential.

The **nature** of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area are assessed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effects will depend on the ecological context. For example, a reduction in reproductive capability of a population would have greater effects on a whale population than on plankton (microscopic organisms living in the ocean) because whales take much longer to mature and produce fewer young over longer periods of time. Effects of a significant magnitude if they cause interruption, alteration, or disturbance of major ecosystem processes such as primary production, consumption, or decomposition. Furthermore, effects may be significant if higher levels of biological organization are affected: 1) A physiological change becomes biologically significant if it affects a characteristic of the whole organism, such as survival or the ability to reproduce; 2) A change in the ability to reproduce among individuals becomes ecologically significant if it affects the size, productivity, or other characteristic of the population; and 3) A change in the size of a population becomes ecologically significant when it affects some characteristic of the community or ecosystem.

Spatial and temporal patterns of effects consider whether effects occur on large scales, (e.g., acid rain), or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves, (e.g., ozone depletion effects on marine ecosystems).

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

DECISION MAKING

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Decision Making

Contents

Work Sheets (WS)

Information Sheets (IS)

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Summary of Decision Making Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Making an informed management decision requires an understanding of the results of the risk characterization, economic and socio-political considerations, and enforceability.
- Decisions involve factoring in uncertainty, tradeoffs, and risks of alternatives.
- Enforceability and evaluation of decisions are issues that need to be addressed in decision making.
- Ecological risk decisions need to be documented to help make future decisions.

Activity

- Consider management options, followed by selection of a well documented final management decision.

Decision Making Phase

A number of factors are considered in decision making, including:

- The results of the risk assessment or risk characterization;
- Economic analyses;
- Socio-political concerns;
- Legal considerations (e.g., enforceability); and
- Options.

Usually, some of these factors play a larger role than others. Whichever decision is made there should be some documentation so that knowledge can be gained from these decisions. Also, consideration should be given to monitoring the effectiveness of the decision so that better decisions can be made in the future.

DECISION MAKING WORK SHEET #1

Option Selection

You have analyzed exposure and ecological effects and have derived an estimate of the ecological risk associated with the Zap-A-Bug Old Warehouse Superfund site. Now, wearing your Risk Manager's hat, it is time to make a decision with regard to remediation of the site and present it to the Regional Administrator before signature of the Record of Decision. Which of the three options do you choose? Why? Be sure to include how your decision addresses the Nine Criteria, public concerns and the ecological risk uncertainties in your presentation.

Decision Made: ______________________________

Justification:

DECISION MAKING INFORMATION SHEET #1

Remediation Options

For this exercise, use the information in the chart below to evaluate three possible remediation options.

Criteria[1]	Options		
	No Action	Limited Action	Extensive Action
	•No activity	•Drum removal •Limited dredging	•Drum removal •Dredging to down-stream of re-charge zone •Pump and treat groundwater and monitor for up to 30 years
Overall protection of human health and the environment	Hazards to several wildlife species expected; including rockfish, avian predators, and benthic macroinvertebrates	Low-level impacts expected for aquatic species; modeled residual exposures to bald eagles may be of concern	Virtually no expected hazards to wildlife resulting from site contaminants
Compliance with ARARs	Violation of State Water Quality Standards	• May be in violation of State Water Quality Standards, depending on cleanup levels • US Army Corps of Engineers permit needed for dredging	• In compliance with State Water Quality Standards • US Army Corps of Engineers Permit needed for dredging
Long-term effectiveness	Over time, surface water/ sediments may become more contaminated from the groundwater source— or may lessen or dilute	Over time, surface water/ sediment contamination may decrease	Expected to remove majority of contamination; site would not be of long-term concern
Reduction of toxicity, mobility, or volume through treatment	No treatment	Yes, somewhat	Majority of source removed
Short-term effectiveness	No change	Ecosystem would require some recovery time	Ecosystem would require some recovery time
Implementability	No change	Possible, but difficult and involved	Possible, but high level of difficulty and long-term involvement required
Cost	$0	$2 5 million	$25 million
State acceptance	Not acceptable	Does not fully meet State background levels	Meets state background levels
Community acceptance	Supported by some Zap-A-Bug employees The environmental group Fix the Fiasco, finds this option totally unacceptable.	Some disapprove as not extensive enough to protect wildlife and ensure permanent solution	Some disapprove as too costly in dollars and time; community economic losses possible

[1] CFR 300.121 mandates that these "Nine Criteria" be addressed in each Superfund Record of Decision.

9. Watershed

9. WATERSHED

GROUP EXERCISE
Dan River Watershed

Contents

Case Study Background and Information Sheets

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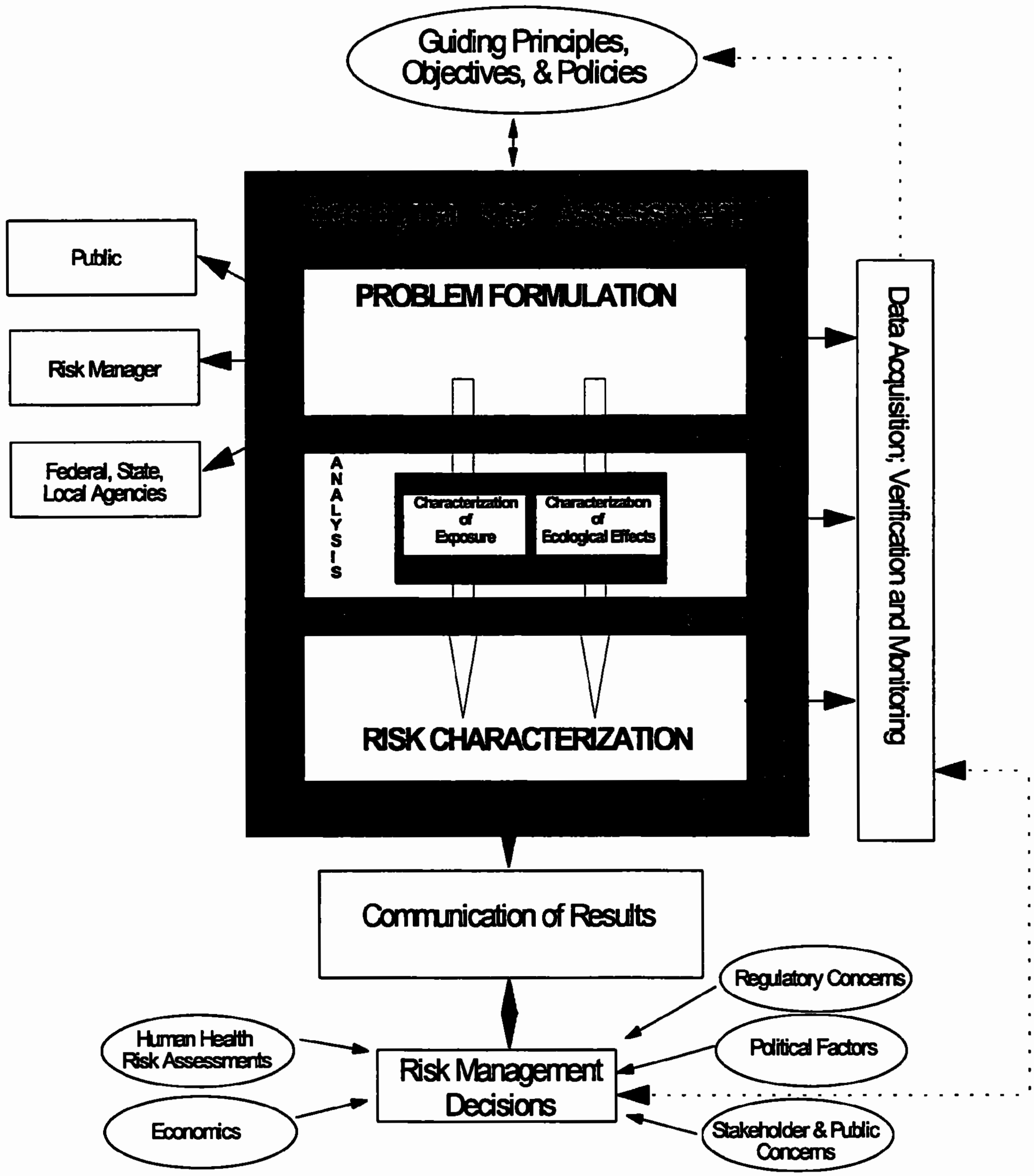

Guiding Principles, Objectives, & Policies
Public
Risk Manager
Federal, State, Local Agencies
PROBLEM FORMULATION
ANALYSIS
Characterization of Exposure
Characterization of Ecological Effects
RISK CHARACTERIZATION
Data Acquisition; Verification and Monitoring
Communication of Results
Regulatory Concerns
Human Health Risk Assessments
Political Factors
Risk Management Decisions
Economics
Stakeholder & Public Concerns

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OVERVIEW OF THE GROUP EXERCISES

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Overview of the Group Exercise

Summary of Group Exercise

In this exercise, you will conduct an ecological risk assessment on a fictitious watershed. At the conclusion of the exercise, you will have three options to consider. Your group will make and communicate a final decision.

Phases of the Group Exercise

The exercise will be conducted in four separate sessions, with a report-out at the conclusion of each phase. These phases will focus on:

1. Problem Formulation
2. Analysis
3. Risk Characterization
4. Decision Making

Materials in This Package

- *Work Sheets.* Work Sheets will guide you through the exercise. Each Work Sheet includes questions or problems for group discussion. Your group should proceed through the Work Sheets in the order they are presented.

- *Information Sheets.* Information Sheets present information on the case study needed for the exercise. This information includes the basic case study background as well as additional case information that will be needed for each of the sessions.

Group Exercise Process

- The Facilitator will gather participants into groups. Each group will choose a leader, a recorder, and one person to report-out the group's recommendations and conclusions.

- Your group is to assume two roles. For the first three phases, your group will complete a risk assessment and communicate results to the decision maker. For the last phase, Decision Making, your group will change roles and integrate the results of the risk assessment with other information needed to reach a management decision.
- Group members will collaborate to develop answers to questions presented on the Work Sheets. You will present your findings to the rest of the workshop participants during the discussion sessions.

Overview of the Group Exercise (Continued)

Key Concepts

1) Develop assessment endpoints in addition to those related to lethality of individual organisms;

2) For watershed ecological risk assessments, cumulative impacts of individual actions and multiple stressors must be considered; also, stressors may originate from outside the watershed.

3) Understand the role of the risk manager in selecting assessment endpoints;

4) Understand the type of measurements used to evaluate exposure and effects to assessment endpoints;

5) Understand the uncertainty associated with the analyses and to carry that through the risk characterization;

6) Appreciate the importance of public involvement in the process; and

7) Understand the complexity and factors involved in decision making including non-regulatory options.

References

USEPA. 1992. *Framework for Ecological Risk Assessment.* EPA/630/R-92/OUI. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

BACKGROUND ON CASE STUDY

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Background on Case Study

Time Allotted

Approximately 30 minutes

Location and Watershed Description

The Dan River lies in the piedmont region of the southeastern United States. The watershed and its tributaries cover about 500 mi^2 of varying terrain characterized by mountain ridges interspersed with broad floodplain valleys with rich soils. The Dan River is part of the headwater system of the Mattapan River that flows to the Atlantic (see map 1). Average preciptation in the Dan River watershed is about 35 inches annually, falling mostly as rain- since snow is infrequent, except in the highest elevations.

The Dan River watershed is comprised of a mosaic of forested lands, agricultural croplands, and grazing lands. The forests are owned privately, and by the state and Federal governments and are dominated by eastern white pine monoculture plantations as well as ridgeline and bottomland hardwoods. Dan's Mountain National Forest, with its granite outcroppings, is highly valued by hikers and birdwatchers. The most accessible and economically valuable timber still remains along the extensive private timber holdings associated with the riparian corridors along the most downstream sections of the Dan River.

The watershed has two medium sized towns (each ~25,000 people). These towns, East Bend and Little Falls are the sites of local commerce and employment as well as the location of the area's two biggest manufacturing plants. The H&T Paper Company has been making paper at Little Falls since 1890 and the Statesman Furniture Company has been milling wood for furniture and hardwood floors since 1855. Both companies derive all their wood from forests within the watershed. They are the major sites of non-agricultural employment in the region.

Crop agriculture is second only to timber and pulp industry in economic importance to the area. Agricultural production in the area focuses on soy bean, lima bean, sweet potato and tobacco. There is a small but growing wine-grape industry in the area. The dairy industry that is made up primarily of small family-farms is now shrinking because of competition from "agro-conglomerates" from outside of the state.

Historically, coal has been extracted from the watershed bedrock using shaft mines and metal ores have been removed using open pit mines. Mining activities in the area ceased 25 years ago.

Background on Case Study (Continued)

Drinking water for the municipalities is from groundwater. Each municipality operates a water treatment facility for treatment of waste water. Treated waste water is discharged into the river at each facility. In addition, each of the two manufacturing operations discharge effluent to the river.

The Ecological Setting

- Much of the bottomland and urban centers have been intensively managed or developed for over 200 years but ridgeline forests and steep slopes in the mountainous areas remain isolated and provide habitat and connecting corridors for wildlife.

- The ridgeline is habitat for several endemic (native) plant species and one species of squirrel that is listed as endangered.

- Nesting perigrine falcons depend on both the ridgelines and rock outcroppings for nest sites and upon the availability of songbirds in the bottomland hardwood forests as prey.

- The riparian corridors along the river provide important nesting and staging habitat (bottomland hardwoods) for several threatened songbird species. The bottomland forest contains rare flowering plants endemic to the area.

- The Dan River below the dam contains refugia for remnants of white and yellow perch, and striped bass populations. The upper segments of the river and its tributaries above the dam support several coldwater fish species, including brown trout, that are important recreationally as well as serving as prey for resident osprey.

Nature of the Issues

Industrial, agricultural, forest products development, and the activities of the human population have had a major effect on the ecology of the Dan River Valley over the last 200 years. Clearing of the land for tillable agriculture, monoculture forest products, dwellings, and other buildings have altered habitat excluding many species or significantly reducing their range and population size. Manufacturing of natural products have historically and continue to produce air and water effluents.

Background on Case Study (Continued)

In each of the two communites within the watershed, publicly owned treatment works (POTWs) also discharge effluents to the river. In some instances, habitat for aquatic species has been altered physically as well — a mill dam at the pulp and paper plant constructed in 1890 blocked the stream as a migration route for anadromous white and yellow perch, and striped bass. The same dam obliterated downstream riffles, rapids, and cold water pools that were important to these species and other non-migratory cold water fish. The re-establishment of these important recreational species is a priority of the State Fish and Game Office.

Runoff from tilled land and clear-cut forest has been a significant source of sediment loading to the stream and clearing of the riparian vegatation as part of agricultural practice has resulted in the loss of shading to the river and its tributaries. The result has been a warmer, slower, more sediment and nutrient-laden stream that is no longer able to support much of the historical flora and fauna. The species that depended on clear, cold, well-oxygenated waters have been replaced to varying extents by species more tolerent of the anthropogenic stresses.

Some Stressor and Source Characteristics

- Many abandoned mines dot the mountainsides resulting in chronic low-level discharges of acidic drainage. Additional atmospheric deposition of metals, including crypton, may be attributable to an incinerator located in another state outside the watershed.
- The prevailing winds carry No_x and So_x into the watershed from power plants outside the watershed.
- Effluent from the pulp and paper mill contains the heavy metals crypton, xenic, and gesium.
- Effluents from the furniture mill include both air and water emissions. The air emissions include dust and particulates from furniture sanding and milling as well as volatile organic compounds (VOCs) that evaporate from staining and finishing tanks. Water discharges are limited to releases from staining and washing tank operations. These compounds include organic materials from stains and wood sealers. There is some evidence that spills or leakage may have occurred from storage tanks out in the mill yard. These tanks contain solvents such as turpentine, stains, and finishes such as polyurathane.
- Continued logging of both private bottomland hardwoods as well as federally held ridgtop forests would have significant effects on remaining migratory and resident species as well as riparian corridors for species that nest elsewhere.

Background on Case Study (Continued)

- Dairy cattle use of riparian corridors along the Dan River and several of its tributaries contributes to the sediment, nutrient and fecal coliform loading to the river and ambient water temperature elevation.

Current Regulatory Activities

* An EPA Region 12 official is reviewing EPA-issued water quality permits associated with two facilities located in the Dan River Watershed; she must also consider whether consultation with the US Fish and Wildlife Service is necessary due to potential impacts to threatened and endangered species from the effluent permitted.

    * The amount of effluent allowed under the pulp and paper and the furniture mill permits will determine the plants' production capacities and associated forest product demand by the mills.

    * Statesman Furniture requested to increase its production, and therefore effluent, by 50%.

    * The permits must be written and signed within 6 months to comply with a court order; the court order was the result of a suit filed by the state which cited delays in EPA processing of effluent permits - EPA admits to backlogs due to staff shortages.

* The State Department of the Environment is reviewing an air quality permit for the Statesmen Furniture Company.

* The Federal Energy Regulatory Commission (FERC) license for the dam at H&T Paper is up for renewal in two years. Currently, the Dam is used by the mill to generate a small amount of electricity.

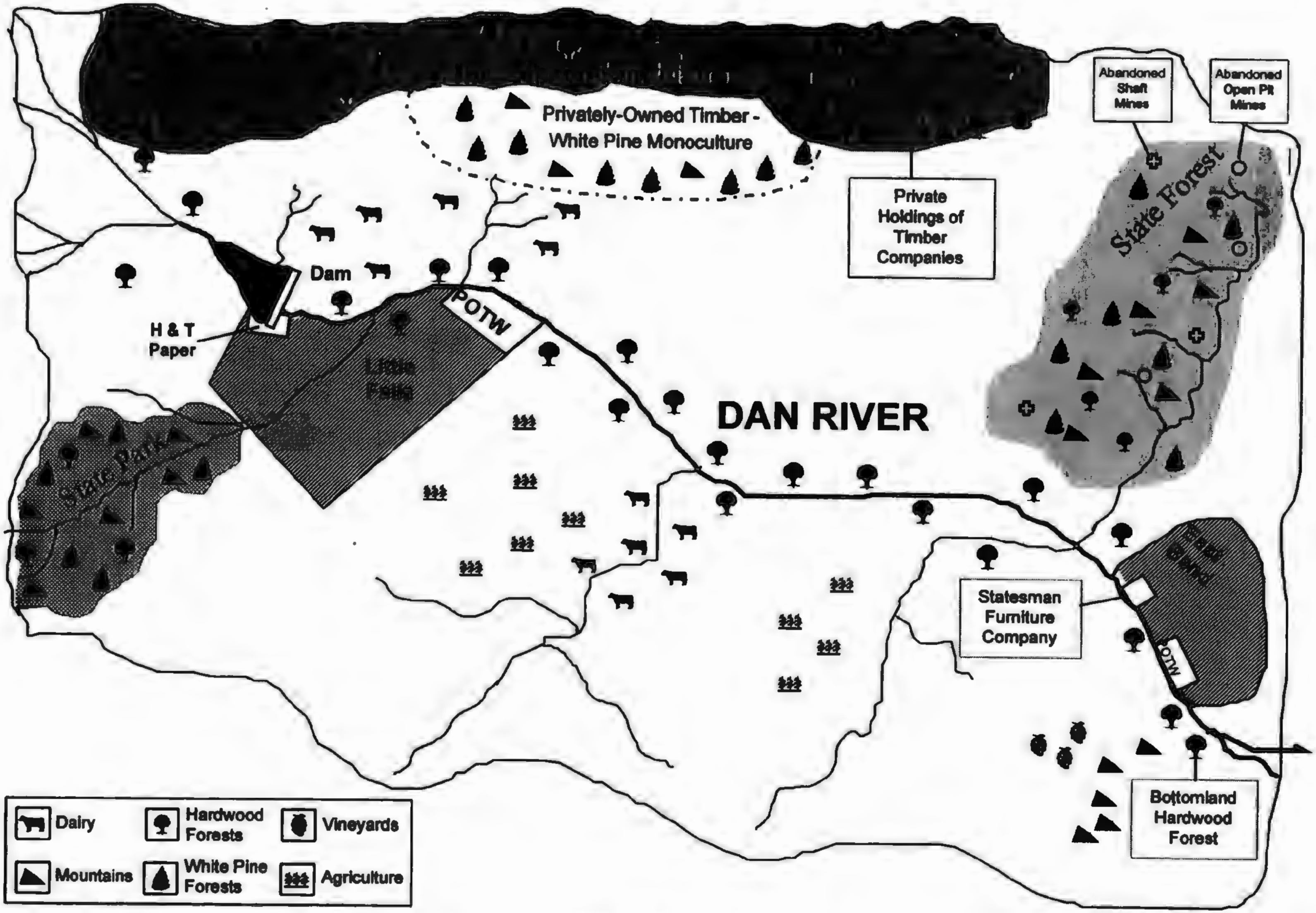

Figure 1: Dan River Watershed

Stakeholders and Their Interests

* EPA Region 12 Division of Water
  (See *Current Regulatory Activities*)

* U.S. Fish and Wildlife Dan River Field Office

  The USFWS is interested in protecting the endangered southern squirrel and is considering listing several species of songbirds which nest in the bottomland forest along the Dan River. They are also concerned about the recent decline of perigrine falcons.

* State Fish and Game Little Falls Field Office

  The State Fish and Game is interested in maintaining the recreational fisheries in the Dan River below the dam including white and yellow perch, catfish, and striped bass populations. Increases in temperature, sedimentation, and pollution from air and water emissions have all adversely effected the fisheries.

* State Department of the Environment
  (See *Current Regulatory Activities*)

  The Natural Heritage Office within the Department of Environment is developing protection programs for rare, endangered, threatened, and other endemic plant species. They are in the process of acquiring riparian land containing bottomland hardwoods to designate as State Preserves.

* U.S. Department of Agriculture Extension Office

  The Extension Office is working with farmers to decrease non-point sources of pollution.

* U.S. Department of Agriculture Forest Service

  The Forest Service is interested in protecting the Dan's Mountain National Forest ecosystem and is considering developing an ecosystem management plan for the forest.

* Federal Energy and Regulatory Commission
  (See *Current Regulatory Activities*)

* Save Dan's Mountain Coalition

  The mission of the coalition is to provide for nonconsumptive wildlife viewing, hiking, and research in the Dan's Mountain area. They are concerned about the recent declines in perigrine falcon populations.

* H&T Paper Company

  H&T Paper Co. is interested in a continued supply of wood from the forests in the watershed and in the re-issuance of its water discharge permit without any expenditures in new equipment to reduce discharges of metals.

* University of the Southeast, Department of Biology

  The USE Department of Biology has been studying the ecology of both the terrestrial and aquatic ecosystems for years.

* Dan River County Commissioners

  The commissioners are interested in addressing problems with the changing economy of the area.

  The Commission is comprised of the president of the Dan's River Chapter of Ducks Unlimited; plant manager of H & T Paper; Charles Griffen of Griffen Logging; a dairy farmer; a developer from East Bend; and a retired city worker from Little Falls.

* Charles Griffen, owner, Griffen Logging

  Mr. Griffen owns much of the private land in the Dan's Mountain National Forest and would like to continue logging in these areas.

* Statesman Furniture Company

  Statesman is very concerned about the renewal of their air emission and water discharge permits and is considering ways of reducing pollution that do not involve high costs.

* State Timber and Forestry Office

  The State Timber and Forestry Office is interested in maintaining the flow of revenue from logging leases but, is under pressure by local groups to work with other agencies to address the natural resource problems of the area.

Background on Case Study (Continued)

Statutory Requirements or Agreements

* The Region 12 water permitting program and non-point source grants are administered by EPA under authority of the Clean Water Act; the watershed is located in a non-delegated state, meaning that EPA is responsible directly for all permit writing.

* The Air permits associated with the off-watershed incinerator are issued by a delegated state in the Region.

* The U.S. Fish and Wildlife Service (FWS), a branch of the Department of Interior, is the Federal agency responsible for administering the Endangered Species Act (SEA) of 1973 for most species. EPA must consult, either formally or informally, with the FWS if EPA determines that its action may affect a threatened or endangered (listed) species or its designated critical habitat. These EPA actions could include registration of a pesticide and any other decision authorized, funded, or implemented by EPA. Also, EPA must confer with the FWS if its action could affect a species or critical habitat that may be proposed for listing. If EPA determines that there will be no effect, consultation is not necessary.

* The Migratory Bird Act, protecting migratory species, and administered by the USFWS

* The FERC has authority to issue permits for dams

* The Dan River County Development Plan: stresses the continued stable economy supported by the widest range of economic inputs (e.g. farming, mining, forestry,) while accommodating a long-term vision of quality public use and recreation on county lands

* The U.S. Forest Management Act, which specifies timber management on federal forest lands and requires the maintenance of viable populations of native flora and fauna, while allowing for managed timber production. The Federal forest lands are managed by the U.S. Forest Service.

* State Timber and Forestry Office - permits and regulates logging, sales and shipment of timber harvested from private forest land leases.

Decision Options

Propose plan to protect and manage the important ecological resources of the watershed which will include both regulatory and non-regulatory options.

PROBLEM FORMULATION

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Problem Formulation

Contents

Work Sheets (WS)

WS #1: Sources of Stressors and Stressors
WS #2: Selecting Ecological Components Affected by Stressors and Exposure Pathways Using the Conceptual Model
WS #3: Management Goals
WS #4: Assessment Endpoints
WS #5: Measurement Endpoints

Information Sheets (IS)

IS #1: Condition of Dan River Watershed Ecosystems
IS #2: Results of Public Meetings Regarding Water and Air Quality Permits
IS #3: Dan River Watershed Management Committee Concerns

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Summary of Problem Formulation Exercise

Time Allotted

Approximately 2 hours.

Key Concepts

- Problem formulation establishes the objectives and scope of the ecological risk assessment.

- Watershed ecological risk assessments consider both terrestrial and aquatic ecosystems and may involve multiple environmental issues, regulatory authorities, management goals, and political jurisdictions.

- The Risk Assessor works with the Risk Manager(s) typically within a forum like an organized group or committee, to identify the objectives and scope of the risk assessment and the assessment endpoints. This includes developing clearly stated goals which are specific enough to develop assessment endpoints.

- An assessment endpoint is a formal expression of the environmental value to be protected and should be ecologically relevant, reflect policy goals and societal values, and be susceptible to the stressor.

- A measurement endpoint is a measurable response to a stressor that is related to the assessment endpoint.

- The public plays an important role in identifying ecological concerns and contributing information.

- The selection of assessment endpoints must be focused to meet the needs of the investigation while reflecting the availability of resources (personnel, financial, time).

Activities

- Identify sources of stressors and stressors.
- Select ecological components affected by stressors and exposure pathways.
- Develop management goals for ecological components.
- Develop assessment and measurement endpoints.

Task Overview

- Complete the Work Sheets referring to the Information Sheets and Background Material.
- Choose a leader and spokesperson to make notes on the flip chart and present a summary of the group discussion. This may be two people or one person may conduct both tasks.

Problem Formulation Phase

The Problem Formulation Phase is where the planning for an ecological risk assessment takes place. The goals, breadth, and focus for the assessment are established in this phase, taking into account regulatory, policy, and public concerns. The Risk Manager and Risk Assessor work together, often within a watershed group or committee, to identify the ecological concerns or effects that are expected or have resulted from human activities. For watershed risk assessments, risk managers may be decision officials in Federal, state, or local governments having jurisdiction over the resources in question, the general public, special constituency groups, or other interested parties. The Risk Manager's role is to ensure societal values are protected and that the risk assessment provides relevant information to make decisions. The Risk Assessor provides information on the scientific characterization of the targeted ecological resources and values or the condition of the ecosystem.

Together, the Risk Manager and Risk Assessor develop agreed-upon management goals after several meetings. The goals should be as specific as possible to ensure that the intent of the goal is met in the risk assessment. This may involve developing sub-goals.

After determining what to assess, decisions are made as to how to assess (i.e., literature search for information, measurements in the laboratory or field, etc.). Factors such as time, cost, and cooperation from other parties are considered when determining how to assess the problem.

Following are some concepts, terms, and tools useful in planning an ecological risk assessment:

Stressors

Stressors are the pollutants or activities that cause the ecological concern or effect.

Generally, the *Framework* classifies stressors as being chemical, physical, or biological. Examples include:

- Chemical-toxics, nutrients (nitrates in water);
- Physical-dredging or filling in waterways or wetlands, diverting water flow in a river by constructing a diversion or dam; and
- Biological-introducing exotic organisms.

Sources of Stressors

Sources of stressors include emissions from factories, farming activities, mining, logging, residential and commercial development, and atmospheric deposition.

Problem Formulation Phase (Continued)

Exposure Routes or Pathways

It is important to trace exposure routes or pathways of a stressor to determine all the possible components of the ecosystem that may be affected. Considerations include:

- Mobility of a stressor;
- Uptake of a chemical by plants and animals;
- Transformation (chemicals may degrade in the environment from ex-exposure to light, or react with water or other chemicals to form substances that are non-toxic, less toxic, or more toxic than the original chemical); and
- Competition (biological stressors).

For physical stressors, the exposure may be immediately obvious (i.e., removing or destroying ecosystems by building a structure, dredging, or removing water for agriculture or drinking water supplies). The effects of physical stressors may be far-ranging, e.g., removal or diversion of water alters habitats downstream (bays become saltier, adversely affecting bay fish nurseries which require a mixture of fresh and salt water).

Ecological Effects

Ecological effects are the harmful responses of the ecosystem and its components to the exposure to stressors. Some examples include death, reproductive failure, decline in growth rate, habitat loss, etc.

Conceptual Models

Conceptual models are helpful in fully characterizing the ecological effects associated with stressors. These models may take the form of sketches of the ecosystem at risk (cross-section or plan view) with arrows illustrating routes of exposure, or they may be abstract in form with ecosystem components and stressors in boxes with arrows showing relationships between them.

Assessment Endpoints

The *Framework* uses the term assessment endpoint to identify the ecological concern(s) that will be the focus of the assessment. Criteria used to select assessment endpoints include:

- Sensitivity to stressors of concern;
- Ecological relevance; and
- Relevance to policy goals and societal/stakeholder values.

Problem Formulation Phase (Continued)

Assessment Endpoints

The assessment endpoint needs to be both affected by and sensitive to the stressor(s). Ecological relevance means that the assessment endpoint is important to the function of the ecosystem. For example, lake trout play an important role in maintaining the balance of aquatic ecosystems. However, the introduction of carp has disrupted the balance of aquatic ecosystems.

Assessment endpoints also should reflect policy goals (e.g., protect endangered species and no net loss of wetlands). Societal values helped form the basis for these policies when environmental laws were enacted. However, policy or management goals (e.g., protect endangered species, maintain recreational fisheries) are not assessment endpoints. Assessment endpoints must be measurable.

Examples of assessment endpoints include: sustainably reproducing populations of trout species; maintenance of populations of aquatic vegetation that are supportive of fish and invertebrates; maintenance of reproductively successful songbird populations, etc. The more specific the assessment endpoint the better, (e.g., loss of no endangered bats).

Measurement Endpoint

Measurement endpoint is another term used in the *Framework* referring to how we determine exposure and effects to an assessment endpoint. Examples of what to measure include concentration of a chemical in water and animal tissue, number of offspring, deformities, mortality, acres of wetlands removed, modeling impacts to a population, status of an indicator species, etc.

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PROBLEM FORMULATION WORK SHEET #1

Sources of Stressors and Stressors

What are the sources of stressors and stressors in the watershed? Use information in the background section including the map of the watershed.

Sources of Stressors

Stressors

PROBLEM FORMULATION WORK SHEET #2

Selecting Ecological Components Affected by Stressors and Exposure Pathways Using the Conceptual Model

What are the ecological components that are being or may be affected by the stressors and what are the exposure pathways? Use the conceptual model or map of the watershed to identify ecological components of concern and to draw arrows representing exposure pathways. Refer to Background Section and Information Sheet #1.

Ecological Component	Exposure Pathways

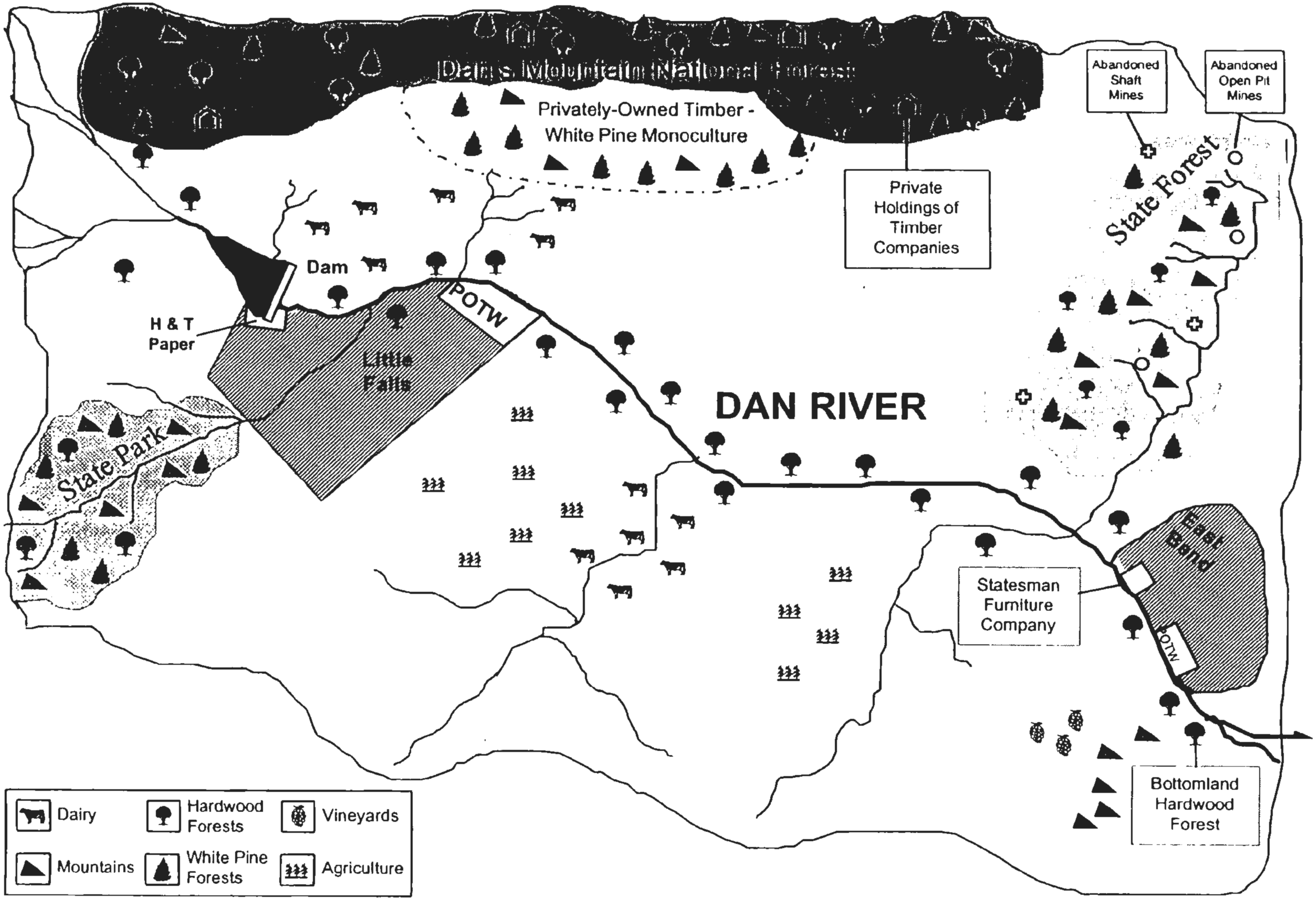

Figure 1: Dan River Watershed
Conceptual Model

PROBLEM FORMULATION WORK SHEET #3

Management Goals

Taking on the role of the Dan River Watershed Management Committee (see Information Sheets 1,2 & 3), develop management goals for the ecological components or resources of concern in the Dan River Watershed.

Ecological Component	Management Goal

PROBLEM FORMULATION WORK SHEET #4

Assessment Endpoints

Using the ecological components on the previous work sheet and the corresponding management goals, develop assessment endpoints for the 4 most important ecological resources of concern.

1. Ecological Component

   Assessment Endpoint

2. Ecological Component

   Assessment Endpoint

3. Ecological Component

   Assessment Endpoint

4. Ecological Component

   Assessment Endpoint

PROBLEM FORMULATION WORK SHEET #5

Measurement Endpoints

1. Prepare a list of measurement endpoints for the 4 assessment endpoints.

Assessment Endpoint	Measurement Endpoints

2. What types of activities would be required to obtain the selected measurement endpoints? What are the real world constraints on an ecological risk assessment and how could these constraints affect your ability to carry-out these activities?

PROBLEM FORMULATION INFORMATION SHEET # 1

Condition of Dan River Watershed Ecosystems

Terrestrial Ecosystems & Components

Bottomland hardwood forests:

As in much of the South, low-lying or bottomland hardwood forests have been cleared along many stretches of the riparian zone due to the high quality of wood and to the desire to plant crops in the fertile soils typical of these riparian areas. Only 40% of the Dan River is currently forested as a result.

White pine forest:

Within Dan's Mountain National Forest, adjacent to the National Forest, and extending outside the watershed are extensive, but fragmented, sections of southern white pine forest. These forests consist of occasional virgin tree stands interspersed with 50-100 year old trees regenerating from large clear cuts at the turn-of the -century. Increased fragmentation within the National Forest is expected to occur as a result of private inholdings decisions to clearcut.

The State Park and Forests contain a mixture of hardwood and softwood species and are lower in the watershed than the National forests; they are heavily used by hikers and campers and provide only minimal habitat for the species of interest in the watershed. Also, they are heavily managed and are criss-crossed with roads; some hunting occurs for white-tailed deer and quail.

Native plant species:

Within the mature hardwood and white pine forest of Dan's Mountain National Forest and in the remaining bottomland hardwood forest are several rare plant species which are found no where else within the watershed. Several are flowering plants of great interest to botanists at the University; one is the State Flower. Both ridgetop and bottomland endemic species are imperilled, some have been recently listed on the State endangered and threatened list. Several of these endemic species, including some which are not rare, are excellent indicators of mature forest type.

Endangered squirrel:

This squirrel species was widely distributed across ridgetop and valley forests well into the twentieth century. Although extensive deforestation in the late 1800's devastated squirrel populations in this watershed, vast refugia existed over a wide extent of the southern mountain systems so that by the 1920's immigration of squirrels resulted in a refurbishment of the local populations. The Dan's Mountain population is one of the only melanized (black) populations of this species. For this reason, the USFWS listed the squirrel in the 1980's as endangered after a reopening of the forests to clearcutting threatened their remaining habitat.

Problem Formulation Information Sheet # 1 (continued)

The squirrel requires a complex forest matrix (mix of tree and shrub types) in order to complete its life cycle. Nesting and foraging occur in different segments of the forest and the species is especially vulnerable to predation when crossing openings in the forest canopy due to its dark coloration. The oldest trees, and those with the most mature understory serve as important refugia for nesting squirrels; offspring are able to move into the less desirable younger stands, but cannot migrate over clearcuts. Some of the squirrel population are located in the ecotone between the white pine monoculture plantation and the mature forested areas, but are vulnerable to owl predation as they attempt to move into the more mature forested areas.

Peregrine falcons, ospreys, and songbirds:

Five pairs of nesting falcons frequent the Dan's Mountain ridgetop, extending beyond the watershed boundary; three reside within the watershed. Peregrines feed primarily on songbirds inhabiting the bottomland hardwood area. The peregrine falcon population has declined recently from eight to five nesting pairs. Disturbance of nest sites along the ridgetop by recreationalists and decline of songbirds are thought to be the cause.

At least seven nesting pairs of osprey frequent the shorelines of the Dan River hunting for fish and nesting along the Dan in and around telephone poles and industrial facilities. Osprey were at one time more numerous, before the establishment of the paper and furniture manufacturing facilities. It is thought that pollutants from these facilities have effected the osprey population both directly through the food chain and indirectly through reduced numbers of prey fish, also thought to be the result of pollutants and riparian land use.

Songbird populations increase during the migration season and provide a relatively stable source of prey for peregrines during the spring nesting season. Several populations of songbirds are on the decline. It is uncertain how much of the decline is the result of decreased survival overwinter in South America, or how much is the result of avoidance of the area due to human disturbance along the Dan River bottomland hardwood forest.

Agro-ecosystems:

Nonpoint source runoff of pesticides used on the crop agricultural is a concern. Best management practices for preventing cattle trampling of the streambank are voluntary and only a few farms limit access to the Dan River and its tributaries. As a result, vegetative cover is lacking on many stretches of the stream and corresponding rises in water temperature are affecting osprey use of the streams for foraging. A recent increase of vineyard development is considered a positive trend but it is unknown what effects will result from fertilizer and pesticide use associated with this new industry.

Problem Formulation Information Sheet # 1 (continued)

Aquatic Ecosystems and Components

River Ecosystems:

Upstream of the Dam:

Upriver of the dam and small reservoir (125 acres), the Dan River is a medium-small sized river that flows year-round, even in the lowest rainfall years. It's average width is 18 feet, its average depth is 4.5 ft and average discharge rate is 13 cubic feet per second (cfs) (range = 6 - 13,750 cfs). The Dan River as a year- round stream extends 31 miles above the dam. At least 200 small streams drain into the Dan between the dam and its headwaters. This segment of the Dan has been designated as a fishable, swimmable water and meets the state water quality criteria in all areas except suspended solids and mineral nutrients. The river has a mix of riffles, rapids and pools. Because of the mineral nutrients inputs from neighboring farmlands, and sediment inputs from farmland and clear-cut forest, this segment of river is starting to experiencing an increase in algae and aquatic weed growth. The tributary streams are also experiencing these changes, although with lower flow, they are sometimes experiencing higher temperatures, low dissolved oxygen and build up of sediments along the bottom. Populations of trout are lower than 50 years ago and their decline appear to be associated with loss of preferred habitat and poor water quality in the tributary streams.

Downstream from the Dam:

Below the dam, although the river is still designated as fishable and swimmable, there are many times during the year that the stream does not meet state water quality standards for that use. In the river along Little Falls, there are noticeable problems with nutrients, oxygen levels and temperature and the rocks and river bottom are covered with algae and aquatic weeds for much of the year; the growth has hit nuisance levels. This stretch of river, has noticeable problems with odor and color as well. During the dry summer months, flow can be reduced below 3 cfs and much of the river bottom in this area can be exposed and partially dried. Sediments in the area immediately below the dam have elevated levels of the heavy metal, crypton. Species that are very tolerant of warm, poorly oxygenated waters are found in this segment of the river, including carp, catfish, and an exotic subtropical species -- the southern canal fish.

Several miles downstream of Little Falls, below the confluence of other tributaries but above East Bend, there are populations of Perch and Striped Bass. A hundred years ago, those species were so abundant that they were fished commercially in this reach of the river. However, today they form the basis of a small recreational fishery.

Problem Formulation Information # 1 (continued)

The Wetlands:

Over the last 50 years about 90% of the wetlands in the watershed have been drained or filled for agricultural or urban development. There has been a significant (better than 85%) loss of waterfowl during that period. The period of loss of wetlands corresponds with the development of many sedimentation problems in the tributary streams and with the reduction in fish populations in the tributaries and upstream, as well.

The Riparian Lands:

Many of the local farmers had cleared their land right to the edge of the water in earlier years, although some are now allowing the brush and trees to grow back -- as part of voluntary best management practices program in the area. The new riparian vegetation is still relatively immature and is not necessarily the same kind of vegetation that occupied the riparian zones in earlier years. Cattle continue to walk through regrowth areas and cleared river bank into the streams on several farms however. The problem is about the same on the tributary creeks that drain the farmland.

PROBLEM FORMULATION INFORMATION SHEET #2

Results of Public Meetings Regarding Water and Air Quality Permits

Under the auspices of the Dan River County Commission, hearings were held on the water quality and air quality permits. The following summarizes the concerns of the public expressed in those meetings:

- A citizen from Little Falls expressed a concern that re-issuing the pulp and paper mill permit would affect the recreational opportunities in the reservoir above the dam;

- Citizens expressed fears about the organic contaminants in the water from the Statesman Furniture Company discharge and possible effects on the health of swimmers;

- A professor in the Department of Biology at the University of the Southeast reported that he has analyzed the catfish and found elevated levels of crypton in their reproductive organs and livers. The professor also noted that sediments taken from below the dam also contained elevated levels of crypton;

- Several citizens said that the odor coming from the water near the paper mill made them feel as if they didn't want to go near the water;

- The state Fish and Game Agency Little Falls Field Office reported two incidents of fish kills over the last three years -- one down stream from the POTW in Little Falls and the other adjacent to the Statesman Furniture Company. They believe the fish kills were caused by unusually high discharges from H&T Paper and the Statesman Furniture Company. They further report that the population of striped bass returning to the stream is markedly diminished over the last 15 years;

- The U.S. Forest Service commented that some trees in the bottomland hardwood forest within a three-mile radius of the Statesman Furniture mill show signs of leaf damage (e.g., bleaching, mottling, stippling);

- The United Brotherhood of Paper Makers, local 1399, commented that they were concerned about the potential loss of jobs at H&T paper if stricter environmental controls were put into place

PROBLEM FORMULATION INFORMATION SHEET #3

Dan River Watershed Management Committee Concerns

A group of agencies, local organizations, and individuals concerned about the condition of various resources in the area and the local economy have organized and held several meetings over the past few years. This group, called the Dan River Watershed Management Committee, hopes to develop a management plan for the watershed which addresses its concerns. The Committee is in the process of developing management goals for the watershed based on its concerns. The following are the major concerns of members of the Committee:

- decline in water quality of the Dan River below the dam;
- decline in sport fishery;
- lack of good swimming areas on the Dan River below the dam;
- loss of natural recreational areas from logging;
- decline of songbird population;
- decline of peregrine falcon population;
- adverse habitat effects of increased birdwatching;
- protect endangered southern squirrel and native plants;
- loss of dairy processing jobs;
- economic effects of possible reduced logging on loggers, H&T Paper, and Statesman Furniture;
- additional costs to farmers to implement any new best management practices; and
- effects of overall changing economy from farming to tourism and the service industry.

ANALYSIS

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Analysis

Contents

Work Sheets (WS)

WS #1: Analysis of Exposure - Upland Forest Community
WS #2: Analysis of Exposure - Recreational Fish Populations
WS #3: Analysis of Effects - Upland Forest Community
WS #4: Analysis of Effects - Recreational Fish Populations

Information Sheets (IS)

IS #1: What is a Geographic Information System?
IS #2: GIS Data Layers and Sources: Anthropogenic Features and Canopy Cover and Type
IS #3: Southern Squirrel Population Characteristics
IS #4: Chemical Exposure Information
IS #5: Physical Stressor Exposure Information
IS #6: Study of Leaf Damage in Dan's Mountain National Forest
IS #7: Minimal Habitat Requirements of Endangered Southern Squirrel
IS #8: Results of Toxicity Tests of Effluent Chemicals
IS #9: Habitat Requirements of Recreational Fish Populations

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Summary of Analysis Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- The major components of the Analysis Phase are characterization of exposure and characterization of ecological effects.

- Exposure analysis requires knowledge of: (1) stressor characteristics (physical, chemical and biological) in environmental media, (2) the probability that ecological components come into direct or indirect contact with the stressor, and (3) the timing of exposure to a stressor in relation to biological cycles.

- Both direct and indirect ecological effects should be addressed. In watershed risk assessments, it is especially important to describe secondary and/or indirect effects within and across media and ecological components.

- Measurement endpoints must be related to assessment endpoints, and this often involves extrapolation from measured individual effects to estimated population and community level effects.

- Risk assessment requires varying degrees of professional judgment in dealing with uncertainties.

Activities

- Analyze exposure routes and pathways, consider stressor characteristics, and identify ecological components of concern.

- Analyze direct and indirect ecological effects.

- Identify uncertainties associated with the analysis phase.

Analysis Phase

The Analysis Phase is where both the exposure and effects of stressor(s) on the assessment endpoints are determined. This phase involves collecting and analyzing data in the literature, actual measurements in the laboratory or field, and modeling. As with any analytical work, there are uncertainties in the data and in interpreting data. These uncertainties should be documented, carried through the assessment, and presented as part of the results to the Risk Manager. Professional judgement is often a component of ecological assessments, and should be clearly identified when the results are presented to the Risk Manager. Similarly, any extrapolations (e.g., from individual to population to community, from laboratory to the field, or from one place to another) should be identified as one of the uncertainties.

Exposure Analysis

It is important to know how stressors behave in the environment, i.e., how solar radiation, water, sediments, soil, air, and the living components affect the movement and form stressors take in the environment. For example, non-affected organisms may metabolize toxic chemicals to non-toxic compounds. Both direct and indirect exposure should be analyzed. An organism may become exposed to a toxic chemical by eating a contaminated organism rather than by direct exposure (consider predator species). Temporal and spatial distribution of a stressor is important. The stressor might affect a certain life stage or the entire life cycle of an organism. The extent of exposure to a stressor could be localized or affect an entire region or large ecosystem.

Effects Analysis

Both direct and indirect effects should be analyzed. Examples of indirect effects are when organisms affected by a stressor are prone to disease, easier targets of prey species, and less competitive.

ANALYSIS WORK SHEET # 1

Analysis of Exposure - Upland Forest Community

1. What are the primary stressors affecting the upland forest community?

2. What is GIS? How is GIS useful in determining exposure of the Forest Community to physical stressors? (see IS # 1 - GIS)

3. How would you characterize the exposure of the upland forest community to logging activities and roads? What are the uncertainties in the data? (see IS # 2 - GIS data layers and source of data)

ANALYSIS WORK SHEET # 1 (continued)

Southern Squirrel Chosen as Indicator Species

The endangered southern squirrel was chosen as good indicator species of upland forest community health. It requires a dense mature forest matrix.

4. How would you characterize the population of endangered southern squirrel in Dan's Mountain National Forest? What is the population distribution? Where are most of the nests found? What are some of the uncertainties in the data? (See IS# 3)

ANALYSIS WORK SHEET #2

Analysis of Exposure - Recreational Fish Populations

1. What are the primary stressors affecting recreational fish populations?

2. What is the exposure of fish populations to these stressors? What are the uncertainties in the chemical exposure data? (see IS #4 & #5)

ANALYSIS WORK SHEET # 3

Analysis of Effects - Upland Forest Community

1. What are the effects of chemical pollutants? (see IS # 6)

2. What are the minimal habitat requirements of the endangered southern squirrel? What are some of the uncertainties in the data? (see IS #7)

ANALYSIS WORK SHEET # 4

Analysis of Effects - Recreational Fish Populations

1. What are the effects of chemicals on the fish populations? (see IS# 8 - Results of Toxicity Tests and Sublethal Tests)

2. What are the habitat requirements of the recreational fish populations? (see IS # 9)

ANALYSIS INFORMATION SHEET #1

What is a Geographic Information System?

- A Geographic Information System (GIS) is a computer-based system used to store and analyze sets of geographic information, referred to as layers, and to generate two- and three-dimensional maps illustrating the relationships among the layers.

- A GIS can use one or more layers to display relationships among physical, socio-economic, ecological, or other spatially-defined data on a map. For example, one layer might contain information on the location of rivers and streams in a watershed, another layer might have information on potential sources of pollution to the system, and a third might contain information on the location and range of important or threatened plant and animal species. A GIS can put some or all of this information onto one map, showing how the data relate to each other.

- While displaying information on a map is very important to help the user understand the interactions among critical features in a given area, a GIS is more than a mapping presentation program. It contains the ability to manipulate and analyze data thus leading to new information. These new data then can be exported and analyzed in other electronic databases. For example, the analyst can have the GIS use different data layers to determine the distance between known or suspected sources of pollution and the habitats of important plant or animal species. This information can then be used in an ecosystem analysis.

- A GIS can help an analyst identify potential stressors to an ecosystem and the relationship among the various stressors. For example, the system can display the location and concentrations of species of concern or other ecosystem attributes and degree of overlap with potential stressors including point sources, roads, and other non-point sources of pollution. This information can be very valuable in identifying the relative impact of different stressors and developing management plans to respond to them.

- While requiring a lot of computer memory to perform multiple and complex operations, GIS software is available to run on personal computers. Most contain baseline data and maps for major metropolitan areas. For most specific, place-based analyses, obtaining and digitizing (converting lines on maps to digital data) relevant data for use in a GIS remains a large task.

ANALYSIS INFORMATION SHEET # 3

Southern Squirrel Population Characteristics

The USFWS conducted the most extensive studies to date of the endangered southern squirrel within the Dan's Mountain National Forest and contiguous white pine monoculture areas. 80% of the dense mature forest, 60% of the re-growth areas, and 50% of the white pine monoculture were surveyed.

The USFWS found the population to be at an historic low. Only 236 squirrels (55 adult males, 45 adult females, and 141 juveniles) were found within the Dan's Mountain National Forest and contiguous white pine monoculture areas.

90% of the squirrel population was found in the dense mature forest, 8% was found in the re-growth area (mostly juveniles and some adult males), and 2% was found in the white pine monoculture. Almost all of the adult females were found in the dense mature forest. Female squirrels are more sedentary and are more sensitive to habitat changes that affect availability of food and nesting sites. All but 3 nesting sites were found in the dense mature forest areas.

ANALYSIS INFORMATION SHEET # 4

Chemical Exposure Information

The chemical exposure data come from a survey conducted by EPA and state Department of the Environment to determine the amount and effects of effluents discharged from H&T Paper and Statesman Furniture as part of the permit review process. The data were collected at fixed stations in the river over a week's period during the summer. Samples were taken from the water (mid-depth for H&T Paper samples only), sediments (grab sample), and adult fish (liver samples from catfish & perch). The sampling stations for H&T Paper and Statesman Furniture were located 100 yards down river from each mill. Samples taken downstream of H&T Paper were analyzed for xenic, gesium, and crypton. Samples taken downstream of Statesman Furniture were analyzed for various organic chemicals contained in the stains and wood sealers.

The results of the samples taken downstream of H&T Paper indicate high levels of crypton in the water, sediments, and fish tissue (see below). Xenic was found at high levels in sediments and fish. Gesium was found at natural background levels.

Results of Samples Taken Downstream of H&T Paper*

Station	Crypton			Xenic	
	Water	Sediment	Fish**	Sediment	Fish**
100 yds	3 ug/l	120 ug/kg	3 ug/kg	400 ug/kg	14 ug/kg

*Above natural background data presented
**Catfish samples

ANALYSIS INFORMATION SHEET # 4 (continued)

The results of samples taken downstream of Statesman Furniture indicate concentrations of only one organic chemical, organostain, well above background levels for fish and sediments (see below).

Results of Samples Taken Downstream of Statesman Furniture*

Station	Organostain		
	Sediments	Perch	Striped Bass
100 yards	124 ug/kg	48 ug/kg	--

*Above background data presented
--no data available; however, life history and feeding habits are similar to perch

ANALYSIS INFORMATION SHEET # 5

Physical Stressor Exposure Information

The state Fish and Game Little Falls Field Office has been collecting data on recreational fish habitat quality and harvest levels for the last 10 and 40 years, respectively. Habitat quality data include water temperature, flow rates, and dissolved oxygen. Sampling sites are at fixed stations along the mainstem every 5 miles above and below the dam. The harvest data is comprised of surveys of recreational anglers at the major boat landings along the river. Harvest data were collected for trout, catfish, perch, and striped bass.

The results averaged over the last summer months (June-August) indicate that the habitat quality measurements are much poorer below the dam versus above the dam (see below).

Habitat Quality Data

Station*	Temp	Flow Rate**	Dissolved Oxygen
1	69 F	11 cfs	7 ppm
2	69 F	12 cfs	6 ppm
3	68 F	9 cfs	6.5 ppm
4	66 F	7 cfs	4.5 ppm
5	79 F	3 cfs	3 ppm
6	77 F	4 cfs	4 ppm
7	78 F	6 cfs	5 ppm
8	76 F	8 cfs	6 ppm

*Stations 1-4 above dam (Station 4 is in reservoir), Stations 5-8 (Station 5 is 5 miles below H&T paper and Station 8 is 5 miles below Statesman Furniture) below dam; all samples collected at mid-depth
**cfs=cubic feet per second

ANALYSIS INFORMATION SHEET # 5 (continued)

The state Fish and Game surveyed the number of recreational anglers and catch for trout, catfish, perch, and striped bass at the major boat landings over the last 40 years. Their data indicate that fishing pressure has remained about the same, i.e., the number of anglers was fairly stable over the last 40 years. However, the catch has declined for all four species, particularly in the last 20 years.

ANALYSIS INFORMATION SHEET # 6

Study of Leaf Damage in Dan's Mountain National Forest

The Biology Department of the University of the Southeast received a grant from the U.S. Forest Service to conduct a comprehensive study of the effects of acid precipitation on forest vegetation. The Service suspected that NOX and SOX emissions from the power plants in another state outside the watershed were the source of acid precipitation in Dan's Mountain National Forest.

The University surveyed the forest for evidence of leaf damage characteristic of acid precipitation, e.g., defoliation, bleaching, mottling, & stippling. Although they found some evidence of leaf damage caused by acid precipitation, most of the forest hardwood trees and shrubs showed no evidence of damage. They concluded that precipitation leaf damage to the forest is very minor but, that follow-up studies should be conducted in the future to monitor leaf damage in case there is an increase in emissions.

ANALYSIS INFORMATION SHEET # 7

Minimal Habitat Requirements of Endangered Southern Squirrel*

Minimum Habitat Area

Minimum habitat area is defined as the minimum amount of contiguous habitat (non-fragmented) that is required before an area will be occupied by a species. For the southern squirrel, the habitat must consist of a dense mature forest matrix. The southern squirrel's average home range is **50 acres** in Dan's Mountain National Forest.

Reproduction

The southern squirrel requires forest vegetation comprised of at least **80%** large dense mature stands of trees and a minimum tract size of **5 acres** for adequate nest sites.

Food

At least **60%** canopy cover is required to produce sufficient supplies nuts to support southern squirrel populations.

* Information derived from a University of the Southeast graduate student (Masters thesis) study funded by the USFWS.

ANALYSIS INFORMATION SHEET # 8

Results of Toxicity Tests of Effluent Chemicals

Toxicity tests were conducted by the EPA and state Department of the Environment on the 3 chemicals found at above background levels - crypton, xenic, and organostain. Both acute and chronic tests were conducted including LD50 and long-term exposures assessing effects on growth, reproduction, and morphology.

The results indicate the levels at which crypton, xenic, and organostain exhibit toxicity and sublethal effects (growth reduction, reproductive effects, and deformities) in catfish, perch and striped bass (see tables below).

LD50 Results

	Crypton	Xenic	Organostain
Catfish	2 ug/l	16 ug/l	---*
Perch	---**	----	42 ug/l
Striped Bass	---**	---	53 ug/l

*Catfish do not occur in exposed area and, therefore, were not tested
**Perch and striped bass do not occur in exposed area and, therefore, were not tested

ANALYSIS INFORMATION SHEET # 8 (continued)

Sublethal Test Results

Chemical	Exposure Concentration	Sublethal Effects
Crypton	1.2 ug/l	Growth rates were significantly reduced in juvenile catfish
Crypton	0.9 ug/l	Significantly lower egg production in adult female catfish
Crypton	3.4 ug/l	Fin deformities in juvenile catfish
Xenic	54 ug/l	Growth rates significantly reduced in juvenile catfish
Organostain	38 ug/l	Juvenile perch exhibited a small but, significant reduction in growth rates
Organostain	31 ug/l	Adult female perch exhibited significant reduction in egg production
Organostain	83 ug/l	Skeletal anomalies in juvenile perch were observed
Organostain	59 ug/l	Growth rates were significantly reduced in juvenile striped bass
Organostain	47 ug/l	Significant reductions in egg production in adult female striped bass
Organostain	71 ug/l	Fin rot was observed in adult striped bass

ANALYSIS INFORMATION SHEET # 9

Habitat Requirements of Recreational Fish Populations

Brown Trout*

Temperature
The maximum temperature that brown trout can tolerate is 72F. Spawning cannot occur above 60F. Brown trout spawn throughout the year.

Dissolved Oxygen
Brown trout require at least 6ppm dissolved oxygen.

Turbidity
Studies have shown that sedimentation causes egg nests to be buried and, under extreme conditions, gills to be clogged.

Catfish**

Temperature
Catfish can tolerate fairly high temperatures (80F) before physiological functions are affected.

Dissolved Oxygen
Catfish will tolerate dissolved oxygen levels of <1ppm but, prefer 4ppm or above.

Turbidity
Catfish typically inhabit waters of high turbidity.

Perch**

Temperature
Perch can survive at temperatures up to 76F but, cannot spawn in waters above 56F. Perch spawn in the spring.

Dissolved Oxygen
6ppm dissolved oxygen is the minimum required for spawning. Adults can tolerate dissolved oxygen as low as 4ppm.

Turbidity
Perch are intolerant of high turbidity waters. They require firm sandy bottom substrates for egg attachment.

ANALYSIS INFORMATION SHEET # 9 (continued)

Striped Bass**

Temperature
Striped bass adults can tolerate temperatures up to 75F. Spawning cannot occur above 56F. Striped bass spawn in the spring.

Dissolved Oxygen
6ppm dissolved oxygen is required for spawning and a flow rate of above 9cfs. Adults generally require highly oxygenated waters.

Turbidity
Striped bass eggs are very sensitive to turbidity and generally will not hatch in turbid waters.

*Information from USFWS species profile

**Information from studies in the literature

RISK CHARACTERIZATION

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Risk Characterization

Contents

Work Sheets (WS)

Information Sheets (IS)

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Summary of Risk Characterization Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Risk characterization is composed of two parts: risk estimation and risk description.

- Risk estimation involves the integration of the analysis of the exposure and effects along with associated uncertainties. Professional judgment may be required in dealing with uncertainties.

- Risk description is a summary of risk estimation and the interpretation of the ecological significance of the estimated risks. Ecological significance considers the nature and magnitude of the effects, spatial and temporal patterns and the effects and potential for recovery.

Activities

- Estimate risk, evaluating effects and exposure data from the analysis.

- Analyze and summarize risk, describing uncertainties and the ecological significance of the risk.

Risk Characterization Phase

The Risk Characterization Phase is where risk is estimated and described. In risk estimation, the exposure and effects analyses are integrated, and an evaluation of risk is made (i.e., the likelihood that exposure to a stressor has resulted or will result in adverse effects). After risk estimation, the assessor determines the ecological significance of the risk. This includes the nature and magnitude of effects, spatial and temporal extent of effects, and potential for recovery. Finally, the risk is described with all assumptions and uncertainties clearly stated.

EPA has issued guidance on risk characterization which state principles that apply to ecological risk assessments including watershed risk assessments. This guidance, found in Appendix E under the title "Risk Policies", calls on EPA to "disclose the scientific analyses, uncertainties, assumptions, and science policies which underlie our decisions as they are made throughout the risk assessment and risk management process." Risk assessors play a fundamental role in this process.

RISK CHARACTERIZATION WORK SHEET #1

Upland Forest Community

1. Compare the exposure (GIS data layers and squirrel population characteristics - Analysis IS # 1, 2, & 3) and effects information (leaf damage and squirrel habitat requirements - Analysis IS # 6 & 7). Make an estimate of risks to the upland forest community based on this comparison. Also, consider risks of future activities (e.g., logging) to the upland forest community.

2. Describe the uncertainties associated with the risk estimate(s).

3. Are the risks ecologically significant? Refer to Risk Characterization Information Sheet #2 - Ecological Significance.

RISK CHARACTERIZATION WORK SHEET #2

Recreational Fish Populations

The Quotient Method

The Quotient Method is a quantitative predictive approach to evaluate risk based on a comparison between an expected environmental concentration (EEC) or dose, and a toxicological benchmark (such as LC_{50}, LOEL, etc.). It determines whether there is a high probability of concern with a particular chemical concentration. It is a tool for ranking a series of contaminant sources by their potential for producing adverse environmental effects.

The Quotient method calculates a ratio using the Toxicological Level of Concern as the denominator. The numerator is the Estimated Environmental Concentration (EEC). A number equal to or greater than one represents a strong likelihood that an ecotoxicological effect of concern will occur. If the number approaches one, the risk is uncertain and additional data are needed to further characterize the risk. A number considerably less than one represents a strong likelihood that an ecotoxicological effect of concern will not occur.

The Quotient Method has several limitations, including:

- It does not adequately account for effects of incremental dosages, indirect effects (e.g , food chain interacctions), or other ecosystem effects (e.g., predator-prey relationships)
- It cannot compensate for differences between laboratory tests and field populations.
- It does not account for multiple chemical exposures.
- It cannot quantify uncertainties or provide a known level of reliability.

1. What is the risk to recreational fish populations from crypton, xenic, and organostain?

RISK CHARACTERIZATION WORK SHEET #2 (Continued)

Recreational Fish Populations

2. Describe the uncertainties.

3. What are the risks to the recreational fish populations from physical stressors? (Refer to Analysis IS #5 - Physical Stressor Exposure Information and Analysis IS #9 - Habitat Requirements of Recreational Fish Populations).

RISK CHARACTERIZATION WORK SHEET #2 (Continued)

Recreational Fish Populations

4. Describe the uncertainties.

5. Are the risks to recreational fish ecologically significant? Refer to Risk Characterization Information Sheet #2 - Ecological Significance.

RISK CHARACTERIZATION WORK SHEET #3

Risk Characterization

1. Assume you are presenting this information to Risk Managers on the Dan River Watershed Management Committee. Write a brief paragraph on your findings. How do you document your conclusions including your uncertainties? Be sure that your paragraph is consistent with the values of clarity, consistency, and reasonableness as outlined in Carol Browner's risk characterization memo (Appendix E).

RISK CHARACTERIZATION INFORMATION SHEET #1

Hazard Quotient Ratios for Chemicals

Crypton - Catfish

Lethal	Sublethal*
1.5	3.3

Xenic - Catfish

Lethal	Sublethal
0.88	--**

Organostain

Lethal

Perch	Striped Bass***
1.1	0.91

Sublethal

Perch	Striped Bass
1.5	1.0

* Sublethal effects concentrations for egg production in adult females used as the toxicological level of concern.

** No data on sublethal effects in adults

*** Organostain concentrations in Perch liver samples used for body burden.

Sample calculation:

$$\frac{\text{Body burden (chemical concentration in fish livers)}}{\text{Toxicological Level of Concern (LD 50 or sublethal effect concentration)}}$$

Organostain, Perch

$$\frac{48 \text{ ug/kg}}{42 \text{ ug/l (LD50)}} = 1.1$$

RISK CHARACTERIZATION INFORMATION SHEET #2

Ecological Significance

Ecological significance pertains to the nature and magnitude of effects, spatial and temporal patterns of effects, and recovery potential.

The **nature** of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area are assessed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effects will depend on the ecological context. For example, a reduction in reproductive capability of a population would have greater effects on a whale population than on plankton (microscopic organisms living in the ocean) because whales take much longer to mature and produce fewer young over longer periods of time. Effects of a significant magnitude if they cause interruption, alteration, or disturbance of major ecosystem processes such as primary production, consumption, or decomposition. Furthermore, effects may be significant if higher levels of biological organization are affected: 1) A physiological change becomes biologically significant if it affects a characteristic of the whole organism, such as survival or the ability to reproduce; 2) A change in the ability to reproduce among individuals becomes ecologically significant if it affects the size, productivity, or other characteristic of the population; and 3) A change in the size of a population becomes ecologically significant when it affects some characteristic of the community or ecosystem.

Spatial and temporal patterns of effects consider whether effects occur on large scales, (e.g., acid rain), or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves, (e.g., ozone depletion effects on marine ecosystems).

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

DECISION MAKING

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Decision Making

Contents

Work Sheets (WS)

WS #1: Upland Forest Community Management Plan
WS #2: Recreational Fish Populations Management Plan

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Summary of Decision Making Exercise

Time Allotted

Approximately 1 hour, 30 minutes.

Key Concepts

- Making an informed management decision requires an understanding of the results of the risk characterization; economic, socio-political, regulatory and non-regulatory considerations; and enforceability.
- Mangement at the watershed level requires a multi-party, cross-program approach.
- Decisions involve factoring in uncertainty, tradeoffs, and risks of alternatives.
- Enforceability and evaluation of decisions are issues that need to be addressed in decision making.
- The rationale for ecological risk decisions need to be well documented to help make future decisions.

Activity

- Identify and develop management options, followed by selection of a well documented final management decision.

Decision Making Phase

A number of factors are considered in decision making, including:

- The results of the risk characterization and associated uncertainties;
- Economic analyses, where appropriate, and associated uncertainties;
- Socio-political concerns (the context within which the decision is being made) and associated uncertainties;
- Legal constraints or mandates (e.g., endangered species protection) and considerations (e.g., enforceability); and
- Regulatory and non-regulatory options.

Usually, some of these factors play a larger role than others. Whichever decision is made there should be good documentation so that knowledge can be gained from these decisions. Also, consideration should be given to monitoring the effectiveness of the decision so that better decisions can be made in the future.

DECISION MAKING WORK SHEET #1

Upland Forest Community Management Plan

You have characterized the risks to the upland forest community. Now as risk managers on the Dan River Watershed Management Committee you must develop a management plan for the upland forest community in Dan's Mountain National Forest. Your plan should consider regulatory actions, non-regulatory options, and any new information that would be useful.

Refer to the Background Section on *Current Regulatory Activities*, *Stakeholders and Their Interests*, and *Statutory Requirements and Agreements*. Take into consideration the results of the public meetings and review the concerns of the Dan River Watershed Management Committee (Problem Formulation Information Sheets #2 and #3).

DECISION MAKING WORK SHEET #2

Recreational Fish Populations Management Plan

You have characterized the risks to recreational fish populations. Now as risk managers on the Dan River Watershed Management Committee you must develop a management plan for recreational fish populations. Your plan should consider regulatory actions, non-regulatory options, and any new information that would be useful.

Refer to the Background Section on *Nature of the Issues, Current Regulatory Activities, Stakeholders and Their Interests,* and *Statutory Requirements or Agreements*. Also refer to Problem Formulation Information Sheets #1, #2, and #3.

10. SUMMARY UNIT

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SUMMARY

This workshop is only one course in EPA's ecological curriculum. The participant should consider taking other courses to learn about different ecosystem protection approaches and appreciate the breadth of this field.

Ecosystem protection is becoming more important at EPA and the limitations and advantages of one tool, ecological risk assessment, were explored. In this course, we provided you with a sampling of a number of ecological risk-related topics: ecology, ecological risk management and decision making, ecological risk assessment, and public communication issues. You should have learned that 1) people hold a wide range of values regarding nature which makes our job more difficult, 2) ecological systems are complex and we do not know everything about natural systems particularly at the ecosystem level, 3) ecological science is evolving and Agency guidance is slowly developing, and 4) public communication and involvement is vitally important to advancing ecological protection.

In conclusion, we hope that this workshop builds a culture of ecological protection in the Agency. We can then more fully factor ecological concerns into our day-to-day activities, including developing regulations, strategic planning, implementing ecosystem management in places, or implementing our national programs.

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11. KEY DEFINITIONS

Stressor: A material, activity, or organism that alters the habitat or environment into which it is introduced.

Chemical Stressor: Chemical leaked into the environment, including hazardous waste, industrial chemicals, pesticides, and fertilizers. These stressors are by far the most frequently investigated during ecological risk assessments.

Physical Stressor: An activity that directly removes or alters habitat, ranging from tilling soil to logging, road construction, and the building of shopping malls. These stressors are often the most destructive because they can result in total habitat loss as soils are compacted and organisms are lost.

Biological Stressor: An organism or microorganism that is introduced or released (intentionally or accidentally) to habitats in which it did not evolve naturally. Such organisms are often called "exotics," and become a concern when they compete against native species, replace them, and become pests.

Primary (Direct) Exposure: The exposure of an organism to a stressor through direct means, e.g., ingestion of a hazardous chemical through fish gills.

Secondary (Indirect) Exposure: The exposure of an organism to a stressor through indirect means, e.g., consumption of contaminated prey.

Direct Effect: The response of the ecosystem and its components to exposure to stressors. Direct effects include death, reproductive failure, and decline in growth rate.

Indirect Effect: Indirect effects occur when organisms become prone to disease, easier targets of prey species, or less competitive as a result of exposure to a stressor.

Assessment Endpoint: The ecological concern that is the focus of the assessment. The endpoint must be both affected by and sensitive to the stressors(s). It should also be ecologically relevant and reflective of policy goals.

Measurement Endpoint: The data from which we determine exposure and effects to an assessment endpoint, e.g., concentration of a chemical in water or animal tissue, number of offspring, and mortality.

Ecological Significance: The nature and magnitude of ecological effects, spatial and temporal patterns of effects, and recovery potential.

The nature of effects relates to the relative significance of effects especially when the effects of stressors on several ecosystems within an area are stressed. It is important to characterize the types of effects associated with each ecosystem and where the greatest impact is likely to occur.

Magnitude of effects will depend on the ecological context. For example, a reduction in reproductive capability of a population would have greater effects on a whale population than on plankton (microscopic organisms living in the ocean) because whales take much longer to mature and produce fewer young over longer periods of time.

Spatial and temporal patterns of effects consider whether effects occur on large scales, (e.g., acid rain), or will be localized, and whether effects are short-term or long-term. Some effects take decades to manifest themselves, (e.g., ozone depletion effects on marine ecosystems).

Recovery relates to how easy it is to adapt to changes. For example, rainforests which are complex, highly evolved ecosystems may take longer to adapt to perturbations than a pine forest, which can recover relatively quickly from disturbances by rapidly re-seeding.

Bioconcentration Factor: The concentration of a chemical in an organism, divided by the exposure concentration. It is often used in ecological risk assessments to help characterize exposure.

Appendix A

ENDANGERED SPECIES POLICIES

OCT 29 199[illegible]

THE ADMINISTRATOR

MEMORANDUM

Subject: EPA Roles and Responsibilities under the Endangered Species Act

To: Assistant Administrators
Regional Administrators

The Environmental Protection Agency has a vital role to play in protecting ecosystems and biological diversity. I have made ecosystem protection one of my highest priorities for EPA. The Endangered Species Act (ESA) is an important tool in achieving this goal because it is designed to protect not only endangered species but the ecosystems upon which these species depend. Based on the endangered species background paper submitted to my office, EPA has a significant role to play in the preservation of endangered and threatened species, but we must take concrete steps to ensure that our ESA obligations are consistently implemented.

In order to strengthen EPA's commitment to protecting endangered species, I have asked the Endangered Species Coordinating Committee (ESCC) under the direction of Deputy Administrator, Bob Sussman, to assist EPA in developing a process to more efficiently and effectively undertake our ESA responsibilities. We are expanding the Committee to include representatives from Region 9, the lead region for this effort, and the program offices. The Committee's task will be to improve the consistency and effectiveness of EPA's efforts to implement its ESA obligations. A focus of this improvement will be to increase endangered species protection without overburdening the resources of the Agency.

As a first step, we are asking the Assistant Administrators and Region 9 to appoint a person to the Committee who is knowledgeable about your ESA implementation activities and is able to represent your office in this effort. In addition, we request that management for all offices participate in a workshop organized by the Deputy Administrator's Office that will take place in early January. Office Directors from each Headquarters Program and at least one Division Director in each Region should plan to attend. The intent of the workshop will be to clarify the ESA Section 7 consultation, affirmative conservation and Section 9 provisions, to exchange information and experiences to date, and to outline steps to be taken to improve our management of ESA obligations.

These steps could involve the development of guidance on the consultation process, negotiation of additional program-specific MOU's with the Fish and Wildlife Service, and the National Marine Fisheries Service, and agreements with the Services to streamline the consultation process. They could also include steps that EPA could take to implement the ESA's affirmative conservation provision.

Please forward the names and phone numbers of your ESCC representative and workshop attendees by November 10, 1993 to Jim Serfis, Office of Federal Activities (mail code 2253, (202) 260-7072).

Carol M. Browner

Carol M. Browner

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 2 1994

THE ADMINISTRATOR

MEMORANDUM

SUBJECT: EPA's Role in the Protection of Endangered Species

TO: Assistant Administrators
Regional Administrators
Office Directors

The protection of endangered and threatened species is integral to the mission of the Environmental Protection Agency. With predictions of 20 percent of animal and plant species becoming extinct within the next 30 years, the maintenance of biodiversity has never been more urgent. Resources protected by the EPA are of critical value to the survival of endangered species, and I believe we must combine efforts to conserve biodiversity with our traditional focus on enhancing the quality of the natural environment.

As you know, I initiated an effort to strengthen our commitment to protecting endangered species on October 29, 1993. This effort is being carried out by the Endangered Species Coordinating Committee (ESCC) under the direction of the Deputy Administrator. One of our first steps was a workshop held on January 12th and 13th, 1994, to clarify the mandates of the Endangered Species Act (ESA), to exchange experiences dealing with endangered species issues to date, and to outline steps to be taken to better meet our responsibilities under the Act.

Bob Sussman has reported to me that the workshop was a great success; the discussion was very candid and many important issues were raised. I would like to restate some principles and suggested actions from the workshop and then describe the next steps.

Endangered Species Principles

EPA has a strong commitment to the protection and conservation of biodiversity and endangered species and their habitats. The scope of our authorities and responsibilities affords us an opportunity to play a major role in this regard. EPA can protect biodiversity through its regulatory authority, its emerging focus on ecosystem protection, its responsibility to monitor environmental indicators, and its research programs. Several suggestions were made at the workshop that could support our commitment. It was suggested that more training and research be done so that we better understand the steps needed to protect endangered species. Several other excellent recommendations resulting from the workshop were using endangered species as an environmental indicator, considering these species as we set environmental standards, and targeting our enforcement actions based on biodiversity concerns.

As the world's leading environmental regulator, EPA should take its legal responsibilities under the Act seriously. For this reason, EPA Regions and programs must become better informed about the legal requirements of the Act. While fulfilling our legal responsibilities under the Act, we must also devise innovative approaches that make our compliance more substantive and efficient. In this regard, workshop attendees suggested that we identify the priority areas needing improvement in the consultation process. It was also suggested that a process be developed to elevate and resolve issues between our Agency and the Fish and Wildlife Service and National Marine Fisheries Service (Services). Another component mentioned was the possibility of counterpart regulations which would allow the Agency to tailor the consultation process to reflect the requirements of EPA programs. All of these suggestions have merit and should be considered.

No single Agency is capable of protecting biodiversity nor is there one single law to achieve those ends. Rather, we must work with other federal agencies to develop a comprehensive approach. For this reason, fostering a productive relationship with the Services is a high priority. To accomplish this objective, it was suggested that we establish working contacts with the Services at many different levels. One particularly good recommendation was to hold a joint retreat to explain how each of our programs operate, share the problems associated with consultation, and discuss how to improve how we work together.

I know that we are facing difficult choices as the Agency simultaneously copes with streamlining, budget constraints, and other uncertainties. We will need to find innovative techniques for maximizing protection of endangered species wisely using our limited resources.

Next Steps

I have instructed the ESCC, under the direction of the Deputy Administrator, to continue to develop an Agency-wide strategy to implement our responsibilities under the ESA using ideas from the workshop. The broad goals of the strategy are to better meet our obligations under the Act, to improve the efficiency of meeting those obligations, to afford better protection to endangered species, and ultimately, to protect the ecosystems upon which endangered species depend.

An important component of the strategy is the development of regional- and program-specific plans. Bob Sussman will be sending a memorandum to you and your endangered species coordinator in the next several weeks that will give more details regarding the content, construction, and timing of these plans. Emphasizing innovative approaches, the plans are to be constructed to fit the needs of the individual program and regional offices, while retaining consistency with general Agency policy on endangered species. The Office of General Counsel has stepped forward to assist program and regional offices in developing plans to meet our responsibilities under the Act and to use the legal mechanisms available to improve management of these obligations.

The strategy will also contain many other necessary elements, including an action plan for improving relations with the Services, the development of model approaches to consultation that focus on ecosystems, and educational programs. As we develop the strategy, we should also be thinking about how our Agency can go from relying on the ESA as a safety net to using our authorities to protect biodiversity, and eventually whole ecosystems. I look forward to working with you on this effort.

Carol M. Browner

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 10 1994

OFFICE OF
THE ADMINISTRATOR

MEMORANDUM

SUBJECT: EPA's Endangered Species Protection Strategy

FROM: Robert Sussman, Deputy Administrator

TO: Assistant Administrators
Regional Administrators
General Counsel
Regional Counsels
Office Directors

The attached Strategy has been prepared as a part of our effort to strengthen EPA's commitment to protecting endangered species. I want to emphasize the importance of this Strategy in meeting our obligations under the Endangered Species Act (ESA) and in finding innovative and effective ways to enhance the conservation of threatened and endangered species. By taking the actions described in the Strategy, we will develop an Agency-wide endangered species program that can offer significant environmental benefits.

A great deal of effort has been put into devising a flexible approach that reflects the needs of the programs and regions. The steps described in the Strategy include review, planning and actions to be taken that address how we will construct a comprehensive EPA endangered species program. Timelines and assignments are given in the Strategy.

With your support we will be able to take fuller advantage of opportunities to use EPA's authorities to conserve biological diversity, protect ecosystems, and meet our legal responsibilities under the ESA. A copy of the Strategy is also being forwarded to each program and regional office representative on the Endangered Species Coordinating Committee. Any questions should be directed to Jim Serfis in the Office of Federal Activities at 202-260-7072.

Attachment

EPA's Endangered Species Protection Strategy

Introduction

The following Agency-wide strategy has been developed to increase EPA's contribution to the conservation of federally listed endangered and threatened species (endangered species). This will occur by using EPA programs to protect endangered species and the ecosystems on which they depend and by implementing EPA's responsibilities under the Endangered Species Act (ESA).

The Strategy is based on the recognition that EPA's authorities and responsibilities afford many opportunities to play an active role in endangered species conservation. EPA will protect endangered species by using its regulatory authority, its non-regulatory programs, its responsibility to monitor environmental indicators, and its research programs. The Agency-wide strategy will, where appropriate, strengthen our commitment to endangered species conservation within the broader context of EPA's emerging focus on ecosystem protection.

Development of an Agency Endangered Species Program

The broad goals of this Strategy are to insure that actions authorized, funded, or carried out by EPA are not likely to jeopardize listed species or adversely affect designated critical habitat; to utilize EPA programs to promote the recovery of listed species and avoid future listings by protecting candidate species; to increase the efficiency with which EPA meets its ESA obligations; to conserve endangered species in ways that are sensitive to resource constraints; to maintain native biological diversity; and to protect the ecosystems upon which endangered species depend.

The Strategy includes review, planning, and actions to be taken by program and regional offices; tasks to be undertaken by the Office of Federal Activities (OFA), the Office of Policy, Planning, and Evaluation (OPPE), and the Office of General Counsel (OGC) in support of these efforts; and cooperative endeavors with the Fish and Wildlife Service and National Marine Fisheries Service (Services). Additional support will be given by the Endangered Species Coordinating Committee (ESCC). The ESCC is composed of representatives from each program and regional office. The role of the ESCC is to act as a source of expertise and a sounding board during the development and implementation of the strategy, as a network for program and regional input to decisions being made, and as a vehicle to share information. Logistical and planning support for the ESCC will be given by a core group made up of OFA, OPPE, and OGC.

The following actions will support the development and implementation of an Agency-wide strategy. Responsibility for each action is given, where appropriate, to program and regional offices or the Endangered Species Coordinating Committee (ESCC).

Actions to be Taken

1) Development of regional- and program-specific plans.

Each regional and program office will develop a draft plan to layout the actions, processes, and procedures to fully implement EPA's responsibilities under the ESA and to further the conservation of endangered species. These plans are to be constructed to fit the needs of the individual program and regional offices, while being consistent with protecting endangered species. The plans will be reviewed and updated, if necessary, on a annual basis.

Since regional plans will be based on program plans, the program offices will submit their plans first, which will be used by the regions to develop their own plans. Regional plans, in addition to including the information below, should stress taking a more ecosystem oriented approach to protecting endangered species.

The draft plans will be reviewed by the ESCC to ensure that the best ideas from each are shared and that there is appropriate consistency in the approaches. <u>Program office draft plans are to be submitted to the ESCC by October 1, 1994. The draft regional plans will be due six months after the completion of the draft program plans and a short review by the ESCC.</u> Final program plans will be submitted by August 1, 1995 and final regional plans three months after their completion and review. Please send submissions to Jim Serfis, Office of Federal Activities (mailcode, 2252). The ESCC will take responsibility for delivering the program submissions to one contact in each region.

Draft plans should be process-oriented and as specific as possible. The following information should be contained in each draft plan:

A. a listing of the types of actions that are currently consulted on, types of actions that will be consulted on in the future, and types of actions that need further review to determine whether they require consultation

B. a description of current or proposed written policy, guidance, MOUs or other mechanism used to address ESA requirements (copies should be attached)

C. current or proposed liaison functions with the Services regarding ESA requirements and ecosystem protection efforts

D. suggestions on how your office or region will use an ecosystem approach for protecting endangered species, where appropriate

E. internal procedures that would be followed to meet ESA Section 7(a)(2) and Section 9 requirements. For example, establishing a process for reviewing actions to determine whether they affect endangered species and identifying how the Services will be contacted for purposes of informal and formal consultation.

F. a process to integrate endangered species considerations into planning and budgeting

G. a listing of opportunities within your programs for promoting the recovery of listed species, for protecting candidate species, and for protecting the ecosystems upon which listed species depend

H. a description of the information and data needs for considering endangered species in EPA decisions

I. an approach on how your program or region will consider endangered species in both current and new state assumed programs

J. a schedule as to when specific actions described in the plans will be undertaken

2) Support for taking an ecosystem approach to protecting endangered species.

The ESCC will coordinate with the Agency's Ecosystem Protection Taskforce. The Taskforce is to implement an Agency-wide ecosystem protection plan. One possible way of coordinating this effort is to emphasize an endangered species component in the demonstration projects that evaluate the principles of ecosystem management.

To assist in the development of plans, the ESCC will come up with examples of ecosystem approaches that could apply to using EPA programs to protect endangered species and to increasing the efficiency of the consultation process. For instance, cross-media actions could be taken in targeted ecosystems to protect a number of endangered species at one time. Another example includes the possibility of consulating on multiple actions that occur in a geographic area rather than on individual actions.

3) Improving cooperation and resolving issues between the Services and EPA.

Several resource and management issues of interest to EPA will be resolved through discussions with the Services. The goal of meetings between EPA and the Services will be to identify specific measures to streamline the consultation process and ways to use EPA programs to protect threatened and endangered species. This effort will begin with high level meetings to develop a process for expeditious resolution of these and other issues. The forums and mechanisms identified in the high level meetings will then be implemented by the appropriate parties. One example of a possible mechanism would be the development of counterpart regulations to fine tune the general consultation regulations in appropriate EPA program responsibilities while retaining their overall degree of protection.

At the same time, a series of workshops will be held to bring Service and EPA staff together to discuss ESA issues. Each day-long workshop will focus on the activities of each program office. The workshops will involve a description of each EPA program, the Service's identification of potential endangered species conflicts, suggestions for avoiding and dealing with the conflicts, and fine tuning the plans developed in action number one. The core group of the ESCC will sponsor the workshops and each AAship will provide adequate technical staff and managers to support each session.

4) Legal Responsibilities and Obligations

OGC will work closely with program and regional offices to resolve legal issues for EPA programs and describe the obligations of the Endangered Species Act relevant to EPA activities together with available mechanisms to improve management of these obligations. This guidance would include, but not be limited to, the following:

- key procedural and substantive obligations under the ESA relevant to EPA, including Section 7 conference requirements, consultation, no jeopardy provisions, affirmative conservation provisions, and Section 9 prohibitions on "take"

- review of common legal issues under the ESA relevant to EPA, including how the ESA may apply to certain types of EPA activities (i.e., permitting, rule making, EPA approval and oversight of state programs, etc.,).

5) Using EPA Programs to Protect Endangered Species

The ESCC, with assistance from program and regional offices, will begin to identify additional opportunities to use EPA programs to promote the conservation of endangered species under 7(a)1 of the ESA. These considerations should be included in the regional and program plans and discussed in meetings and workshops. In addition, several other forums will be used to generate opportunities, including brainstorming sessions with program staff, solicitation of suggestions from the Services and outside experts, and workshops.

6) Educational Programs

Educational programs will be undertaken to train EPA and the Services regarding EPA responsibilities and opportunities under the Act. Discussions with the Services will be initiated to consider support for training and to tap into existing training. Initially, this effort would start with short courses followed by the establishment of more long-term training programs.

7) Development of Information and Tools

The Office of Research and Development will, in cooperation with the Services, work with program offices to identify and develop information and tools needed to make credible scientific decisions regarding the protection of ESA species.

8) Accessing Needed Information

The Office of Administration and Resources Management (OARM) will provide core, common-use information such as data bases of listed and candidate species, occurrence locations, and critical habitat locations. OARM will also provide supporting information technologies, such as geographic information system analytical tools and base data coverage, and access via the Internet computer network to other entities' information holdings.

9) Centralized Agency-wide Functions

Options will be developed for centralized Agency-wide functions that would be administered by the Office of Federal Activities. Such options could include core staffing with regional counterparts to serve as a source of expertise and clearinghouse for information; database management, in coordination with OARM, to benefit all programs and regions; liaison function with the Services; and coordination of counterpart regulations or guidance between agencies. The ESCC will develop options for structuring these functions within the next three months.

10) Management Planning and Actions

Management plans and actions will be adjusted to include endangered species activities into program planning. This includes amending work load models, SPINs, and budget planning. These adjustments are to be considered in the regional and program plans. Further suggestions would be made as the plans are implemented.

EPA ENDANGERED SPECIES ACT RESPONSIBILITIES:

RELATIONSHIPS TO RISK ASSESSMENT AND ECOSYSTEM MANAGEMENT

BACKGROUND

In October, 1993, Administrator Browner issued a Directive to all EPA management regarding our responsibilities under the federal Endangered Species Act (ESA). This directive ended several years of confusion as to the extent of our responsibilities under this law. At the time of the Directive's issuance, there were at least 11 legal actions challenging EPA's failure to consult under Section 7(a)(2) of the ESA. In particular, the Directive clearly states that EPA will comply with law's requirement that federal agencies consult on any action which is authorized, funded or carried out by EPA, including approvals or disapprovals of state delegated actions which may affect species listed under the ESA.

The Administrator established as policy EPA's full compliance with the letter and spirit of the ESA. In addition, the Administrator expanded the Endangered Species Coordinating Committee to include all media offices, as well as OPPE, OFA and OGC. A January 1994 two-day management workshop was chaired by Deputy Administrator Sussman and attended by over 70 EPA managers. Follow-up instructions to Regions and Programs to develop ESA implementation plans are in progress.

It is widely recognized that the ESA will not alone be successful in slowing the rate of listings and extinctions, nor recovering listed species unless federal partners such as EPA bring their considerable authorities to bear on the conservation of endangered species and their habitats, as well as biodiversity in general. The ESA was originally written with this in mind and assumed that other federal environmental mandates would provide the mechanisms necessary to protect our nation's biodiversity. Unfortunately, this has not been the case and the ESA "safety net" against extinction has become the primary mechanism to assure adequate protections for our living resources.

EPA RESPONSIBILITIES UNDER THE ESA

- o REQUIREMENT TO CONSULT (Section 7(a)(2)

  - * All federal agencies required to consult with the Services on any actions funded, authorized, or carried out by the agency which affect T&E species

  - * Courts have taken the consistent position that the ESA takes precedent over other federal mandates

  - * Responsibility of "action" agency to identify potential "may affect" actions and to initiate consultations

- o FORMAL AND INFORMAL CONSULTATION

  - * Informal consultations can be initiated by letter or phone call; if a "no adverse" effect determination is made in consultation with the Service, consultation is terminated and the agency can go forward with action

  - * Important to keep a thorough administrative record of decisions

  - * Formal consultation is initiated if the action is thought by the agencies to have an adverse affect on T&E species

- o AFFIRMATIVE CONSERVATION (Section 7(a)(1)

- o PROHIBITION AGAINST "TAKE" (Section 9)

IMPORTANCE OF EPA MEETING ITS OBLIGATIONS UNDER THE ESA

- * Resources protected by EPA statutes are of critical importance to listed species:

  - \- 85% of all listed species utilize wetlands and aquatic habitats

  - \- 52% of 920 listed and proposed species are affected by pollution

- * The ESA is a fundamental environmental law and has been interpreted by the courts as superseding other federal legal mandates

- * Currently 11 legal actions against EPA for failure to consult under Section 7(a)(2) of the ESA; EPA forced to settle out of court on Mudd vs Reilly (Alabama)

* Over 800 species are currently listed; 400 more will be soon; more that 6000 await listing

- o CONSISTENT WITH EPA MANDATES

- o OPPORTUNITIES UNDER EPA'S NEW ECOSYSTEM MANAGEMENT POLICY

ECOLOGICAL RISK ASSESSMENT AND THE ESA

The ESA requires EPA to assure that no "harm" (widely defined as harassment, disturbance, etc.) come to individuals of a species listed under the Act. Section 9 of the Act prohibits "take" which includes harm as well as killing a listed species. There are criminal liabilities for such action against a listed species. The law also prohibits "jeopardy" to a species; such determination is made by the Services and includes species, population, and genetic standards to assure the continued existence of a species; although the benchmark for jeopardy varies with species and circumstance, Service standards of roughly less than 5-10% population loss frequently constitute jeopardy to a species. The most thorough "risk assessment" conducted on a listed species is found in the Interagency Scientific Committee's Conservation Strategy for the Northern Spotted Owl.

EPA approaches to ecological risk assessment which focus on populations and communities of organisms without considering effects to individuals organisms are generally not useful in supporting EPA management actions regarding T&E species. Widely used water quality criteria, for example, are formulated based on assumptions that 85% of all aquatic species would be protected by those criteria. As EPA begins to increase dramatically its response to T&E species needs, and increases consultations with the Services, traditional risk assessment approaches will need to be modified to assist in determining risks to listed species. The Office of Pesticides Programs, in conjunction with the FWS Environmental Contaminants experts, are charting the course in making toxicity-based risk assessments relevant to ESA assessments. New efforts in modifying water quality criteria may also be of help in supporting EPA's responsibilities to protect listed species.

Scientists involved in the Agency's risk assessment process can assist by developing appropriate extrapolations methodologies for inter-species toxicity determinations, determining appropriate uses for safety factors, etc. Although the biological determination of "harm" and "jeopardy" will most often be the province of the Services, EPA will be better placed to take the necessary protective measures for listed species if we advance our knowledge and capabilities in these areas.

BENEFITS TO ESA FROM ECOSYSTEM MANAGEMENT

There are two major responsibilities under the ESA which the Ecosystem Management Initiative can facilitate: 1) the affirmative action responsibilities under Section 7(a)(1); and 2) the federal consultation requirements of Section 7(a)(2). Section 7(a)(1) requires that EPA utilize its authorities to further the goals of the ESA. These goals include the protection, conservation and recovery of threatened and endangered species (T&E species), and protections for species which have been proposed for listing - the "candidate" species group - currently over 6,000 species.

Section 7(a)(1) is EPA's best opportunity to use ecosystem management planning to further the goals of the ESA. Two obvious opportunities are to: (1) build in protections to rare, sensitive and candidate species **before** they are listed, assisting in pre-listing recovery by instituting species conservation actions into ecosystem plans; and (2) incorporating measures to protect and recover listed species; this might include participation in Habitat Conservation Plans (HCP"s) under Section 10 of the ESA [private and state equivalent to consultation under Section 7(a)(2)], or commitments to institute actions necessary for recovery of species.

The federal consultation requirement of the ESA, Section 7(a)(2), may, in some cases, lend itself to broader, ecosystem approaches. Although "ecosystem " consultation has not been tried before by the Services, recent attempts to consult at a "programmatic" level are being considered in the Great Lakes Initiative. Presumably, after consulting on a large plan, such as the GLI, individual consultations at the species level would be facilitated.

At this time, it is not likely that the Services (U.S Fish and Wildlife Service and National Marine Fisheries Service) would agree to consultation on the effects of a particular ecosystem plan on T&E species without additional consultations on specific actions like permit issuance; the reasons for this are numerous, and include issues of accountability for actions necessary to avoid risks to species, as well as legal requirements to consider risks to species individually. However, this idea has wide support at EPA for both efficiency and effectiveness reasons, and a demonstration ecosystem management plan might be an appropriate testing ground for this approach.

Appendix B

ECOLOGICAL RISK: A PRIMER FOR RISK MANAGERS

Appendix C

COMMUNICATING WITH THE PUBLIC ON ECOLOGICAL ISSUES: CLARK UNIVERSITY STUDY

COMMUNICATION WITH THE PUBLIC ON ECOLOGICAL ISSUES: INSIGHTS FROM RELATED LITERATURE

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Contents

**Communication with the Public on Ecological Issues:
Insights from Related Literature**

Michael J. Dover
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I. Introduction

This paper examines findings and concepts relevant to effective communication on ecological issues, particularly as it applies to communication between government agencies and the public. **Ecological issues** are those that involve primarily nature and natural resources, especially the potential adverse effects of human activities on natural systems. The literature reviewed here is from a diverse set of disciplines, such as social and behavioral science, education, philosophy, and law. In particular, we examine writings on risk communication (focused primarily on human health and safety), public attitudes toward nature, environmental education, and alternative dispute resolution, to provide some insight as to how communication on ecological issues can most effectively develop as a field of practice and research.

The U.S. Environmental Protection Agency (EPA) has in recent years focused increased attention on its role in assessing and managing ecological risks—the actual or potential harm to plants, animals, and other components of natural systems caused pollution, physical alteration of the environment, and other anthropogenic stressors. While protection of human health remains a high priority, policy makers and the public are becoming more aware of:

- The economic, recreational, aesthetic, and other values placed on ecosystems and natural resources; and

- The link between the well-being of the human population and the effective functioning of the natural world (SAB 1990).

More recently, EPA has also begun exploring possible roles in ecosystem management, working to maintain natural systems and human interactions with those systems in a sustainable fashion. As part of its responsibility to make decisions and undertake other activities for protection of natural resources, EPA has long understood the importance of effective communications between the Agency and other stakeholders in the debates that take place. As EPA's interest and involvement in ecological issues expand, so too will its need to communicate effectively about those issues.

While a considerable body of literature and experience exists concerning communication on human health and safety, ecological issues can pose different challenges to communicators. Just as ecological risk assessment differs in fundamental ways from human health risk assessment, so too does communication about ecological issues need to be developed taking such differences into account. To take one simple example, debates over human health risk agree on what species should be studied and protected, whereas this may be one of the first items of discussion in an ecological controversy. The purpose of this review is to examine some of these similarities and differences and to summarize findings or perspectives from a variety of disciplines, which may help to define how communication strategies concerning ecological issues can be developed in the future. By its nature, such a review cannot be comprehensive; rather, its intent is to identify, where possible, seminal or review publications that contain relevant ideas and experience from their respective disciplines.

This review covers four principal topics. Section II discusses the applicability of insights from the risk communication field, which has focused on human health and safety, to ecological risk. Section III examines public views of nature as a factor in understanding the process of communicating on ecological issues. Section IV briefly reviews two areas, environmental education and alternative environmental dispute resolution, which can cast some light on the communication process. Finally, Section V concludes with suggestions on next steps to take in developing the field of ecological-issues communication.

II. Applicability of principles from human health risk communication

A. Basic concepts

Early research in risk communication reflected government agencies' efforts to bring the public's perceptions of health and safety risks into greater agreement with scientists' and regulators' views of those risks. The focus was primarily on the "risk message"—how to present information on "real" risks to offset "perceived" (i.e., misperceived) risks. By the late 1980s, however, understanding of risk communication had evolved considerably, so that the National Research Council (NRC) report on the subject (NRC 1989) focused on the *process* rather than the message:

> *Risk communication is an interactive process of exchange of information and opinion among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management.*

This focus on process rather than product leads also to a broader notion of the purpose of risk communication. In the view of the NRC, success is no longer defined in terms of changing people's minds or obtaining agreement with the communicator's (e.g., a regulatory agency's) position or decision. In keeping with the larger goal of supporting "democratic decision making and well-informed, goal-directed individual choice," the NRC asserts that:

> . . . *risk communication is successful to the extent that it raises the level of understanding of relevant issues or actions and satisfies those involved that they are adequately informed within the limits of available knowledge.*

Deriving from this definition of success are three key points:

- Successful risk communication does not always lead to better decisions because risk communication is only part of risk management.
- Successful risk communication need not result in consensus about controversial issues or in uniform personal behavior.
- Messages about expert knowledge are necessary to the risk communication process; they are not sufficient, however, for the process to be successful. (NRC 1989)

These definitions and principles, although focusing on human health and safety, speak more broadly to the subject of communication and decision making on technical/scientific issues within a democratic society. As such, they serve as a foundation for communication on ecological issues without amendment. Differences between the two types of communication begin to emerge when examining the knowledge needed for risk decisions, and the public's perceptions and understanding of health and ecological issues.

B. Knowledge needed for decisions about health and ecological risks

Risk assessment depends on knowledge about the sources and nature of potential harm (commonly called *hazards* in health risk assessment and *stressors* in ecological risk assessment), the likely exposure and its distribution, the sensitivities of exposed individuals and groups, and interaction with exposure to other possible sources of harm. *Risk management* requires the results of that analysis, combined with information on alternative actions, uncertainties associated with the risk and alternatives estimates, and managerial constraints and dictates concerning the risk decision (NRC 1989). Differences between health and ecological risk with respect to risk assessment and management, and some implications for communication, are discussed below.

1. Hazards/stressors of concern

Evaluation of hazards or stressors includes identification of who or what might be harmed and the nature of the potential harm. It also includes evaluation of the seriousness of the harm and the potential for reversibility.

An essential difference between health and ecological risk assessment occurs at the beginning of this process: there is no *automatic* consensus in ecological risk assessment as to what (one or more) species is or should be the focus of concern when evaluating possible stressors. (Given a particular environment, ecologists and others may quickly come to agreement as to what should be studied and why, but it does need to be discussed. Standard test organisms and protocols have been agreed upon for evaluating such stressors as pesticides and wastewater, but their interpretation with regard to other species in the environment can be the subject of debate.) Other controversies certainly occur in health risk assessment (e.g., effects of age, sex, socioeconomic status, etc. on the analysis), but there is no disagreement that the only species of concern is *Homo sapiens*. Communicators dealing with ecological issues may need to take this difference into account. Participants in a communication may not agree on what species, stressor, or effect is important with regard to a particular issue.

A second major difference at this stage concerns level of organization. Ecologists do not usually focus on individual organisms when determining risk (except in cases of rare or endangered species). Often, concern is for effects on populations or subpopulations of a species, which parallels the level of organization most common to health risk assessment. In many instances, however, investigators turn their attention to communities and ecosystems in order to understand the full implications of a potential for harm. Such terms as "biotic integrity" and "ecosystem health" express scientists' interest in protecting and managing these higher levels of organization. Appropriately, the EPA Risk Assessment Forum chooses to use the generic term "ecological component" to capture the range of organizational levels that might be involved in an ecological risk assessment (RAF 1992). [The term also reflects the fact that ecological effects of stressors are both direct and indirect (see the discussion below), and therefore replaces the toxicological term "receptor."] Some members of the public may have an incomplete understanding or significant misunderstanding of such concepts as populations, communities, and ecosystems (Munson 1994), which could pose a challenge to communicators trying to explain agency judgments (e.g., design or results of studies, rationale for a management decision) or seeking public input concerning an ecological issue.

Whereas health risk assessments typically examine only the direct effects (e.g., cancer, birth defects) of a potentially harmful agent or activity, ecological risk assessments also may consider indirect as well as direct effects in the identification and evaluation of stressors (and, concomitantly, of potentially affected ecological components). Indirect effects include loss of food sources, nesting or breeding sites, or some other resource needed for survival. They could also include behavioral changes that affect organisms' ability to avoid predators, obtain food, find mates, or rear young. Indirect effects also play an important role in evaluating potential hazards to communities and ecosystems, where interactions among populations determine the structure and functioning of these organizational levels. For certain ecological issues, it may be important for communicators to ensure that audiences understand the significance of indirect effects with respect to an assessment or management decision.

Reversibility in health and ecological risk can have considerably different meanings. Ecological risk assessors may ask whether a population, community, or ecosystem can recover from a disturbance (e.g., chemical contamination) and, if so, how long recovery might take. Such recovery might take years, spanning several generations of affected species. In health risk assessment, reversibility over more than one generation would rarely be considered acceptable. In debates concerning ecological effects of stressors, communicators may need to be aware of differences among interested parties about what constitutes acceptable recovery and recovery times.

Evaluation of ecological stressors includes a broader array of possible sources of harm than are typically found in health risk assessments. Although the term "risk" is often associated in the public and regulatory arena with potentially toxic chemicals, organisms in the natural environment are subject to numerous anthropogenic and non-anthropogenic stressors. Physical disturbance of habitat can cause direct mortality to resident organisms (e.g., siltation that buries bottom-dwelling aquatic organisms), or can make the environment less habitable (e.g., the same siltation might also increase the turbidity of the water, allowing less light to penetrate and thus limiting the ability of aquatic plants to grow). The most extreme of physical stressors is complete loss of habitat through development or other alteration, which can render the area unusable by its original inhabitants. Indeed, habitat loss is seen by many experts to pose the greatest ecological risk of all (SAB 1990). Biological stressors such as accidentally (or intentionally) imported species can wreak havoc in local or regional ecosystems by competing with or preying on indigenous species. Responding to such adverse ecological effects as these can require sophisticated understanding of complex interactions among physical, chemical, and biotic components of the environment. Communication about such stressors and their effects may require providing considerable information about ecological structure and function in a way that non-technical audiences can understand and relate to the issue.

2. Exposure and sensitivity

Evaluation of exposure considers a broad array of factors to determine who or what is exposed to a hazard, how many people or organisms (or, more generally, ecological components) are exposed for how long, how exposure is distributed among different groups (subpopulations of people, populations or subpopulations of species, community or ecosystem types), and how exposures to the hazard(s) or stressor(s) of concern interact with exposures to other hazards/stressors (NRC 1989). Although the term "exposure" is commonly used in the context of toxicological studies, the EPA Risk Assessment Forum applies the term broadly to include contact with other stressors (RAF 1992).

Differential sensitivities to potentially harmful agents among human subpopulations can lead to important considerations of equity and fairness in risk management and risk communication. Ecological risk assessment must evaluate a much larger and more diverse assortment of possible responses (in terms of both the nature and magnitude of response) among potentially exposed species. For example, some synthetic pyrethroid insecticides have relatively low mammalian toxicity, but can be quite harmful to fish. Ecologists recognize numerous pollution-tolerant species that often serve as indicators of a disturbed condition at a site, but which also illustrate the different sensitivities that occur in nature. Even closely related species can differ significantly in their susceptibility to potential toxins (Calabrese and Baldwin 1993).

Both exposure and sensitivity may be difficult concepts to communicate with respect to potential ecological harm. On one hand, some people may assume that if a pollutant is present it will cause harm. On the other hand, laypersons may not distinguish between tolerant and sensitive species and so may not recognize that a problem exists. Communicators may need to work with fairly complex information to explain scientific evaluations of exposure and sensitivity to such audiences.

C. Perception and understanding of risk

Among the key contributions of research in risk communication has been a greater understanding of how risk is perceived by laypersons and others. This research is significant because it helps explain the apparent differences between what experts and the public consider important risks, and how those differences affect the risk-communication process.

Virtually all of the research in this area concerns people's perception of risk to themselves or other human beings, but some observations may be applicable to ecological risk. The table on the following pages lists various factors (from Covello et al. 1988) that influence public concern about the risks that they encounter. The table also comments on the applicability of each factor to considerations of ecological risk, including questions that might be asked in a research program to understand better the ways in which various publics perceive ecological issues.

McDaniels et al. (1995) conducted a study to evaluate respondents' perception of a wide variety of ecological risks and of human activities that might affect those risks. They examined five factors in relation to perceived overall risk to nature. The first, which they labeled *impact on species* included concern for loss of species and suffering by animals or plants. A second factor, *impact on humans* implied that ecological risks and health/safety risks are perceived as related, while a third, *human benefits*, appeared to offset ecological concerns. A weak correlation was found between a factor called *knowledge of impacts* and risk to nature, suggesting that risk is perceived to be higher the more we are able to observe, predict, and understand ecological effects. Finally, in contrast to studies of risks to human health and safety, no correlation was found between risk to nature and a factor called *avoidability/ controllability*, which encompassed such issues as current levels of regulation and resources spent on "preparing for, and responding to, the consequences of the events." Among their other results, McDaniels et al. found less concern for ecological effects of natural disasters than for impacts of human activity, and an apparent lack of understanding about the relationship between ecological consequences and their human causes (e.g., ozone depletion and refrigeration using CFCs).

Perception of risk is not only a matter of individual judgments about personal risks but also an expression of societal values, such as fairness and democratic due process (NRC 1989). Such values as economic worth, aesthetics, utility, and morality may enter into how stakeholders perceive ecological issues, including risk. For example, Suter (1993) argues that the choice of species and effects to be studied in an ecological risk assessment (and, presumably, protected in subsequent risk-management actions) is determined in part by their "social relevance," although he appears to leave the decision to individual assessors and managers as to what is socially relevant. That decision may be difficult. Section III of this review discusses some of the disparate views of nature that may affect public perception of what is or is not important in ecological management. The current political debate over whether to reduce the authority of the Endangered Species Act suggests that ecological issues compete more with other values such as economics and private property rights than do health issues. As another example of the importance of such competing values, valuation of human lives in dollar terms as part of risk management remains controversial, whereas the monetary value of ecological resources (the word "resource" itself connotes assigning of some economic value) is commonly considered in risk-management decisions. (The controversy over placing a value on ecological resources usually lies more with *how* such a value will be determined than with *whether* it should be determined.)

Qualitative factors affecting risk perception and evaluation

1 Factor	2 Conditions associated with increased public concern	3 Conditions associated with decreased public concern	4 Applicability to ecological risk
Catastrophic potential	Fatalities and injuries grouped in time and space	Fatalities and injuries scattered and random	Does the public pay more attention to highly visible events (e.g., fish kills, oiled birds) than to gradual or subtle effects?
Familiarity	Unfamiliar	Familiar	What types of ecological risks are familiar or unfamiliar (e.g., development vs. chemical contamination)?
Controllability (personal)	Uncontrollable	Controllable	What is the perceived connection between ecological risk and personal risk? Are ecological risks perceived as subject to personal control?
Voluntariness of exposure	Involuntary	Voluntary	All ecological exposure is involuntary. How does that affect public perception?
Effects on children	Children specifically at risk	Children not specifically at risk	Not applicable
Effects manifestation	Delayed effects	Immediate effects	Possibly the opposite for ecological effects (see catastrophic potential, above).
Effects on future generations	Risk to future generations	No risk to future generations	Do ecological issues include intergenerational concerns? That is, do members of the public consider questions of the "legacy" to future generations when evaluating the importance of an issue?
Victim identity	Identifiable victims	Statistical victims	Do "charismatic" species receive more attention from the public than "ordinary" species?
Dread	Effects dreaded	Effects not dreaded	Not applicable
Trust in institutions	Lack of trust in responsible institutions	Trust in responsible institutions	Trust issues may also include concerns over economic loss due to risk-management decision (e.g., spotted owl).

Qualitative factors affecting risk perception and evaluation (cont'd.)

1 Factor	2 Conditions associated with increased public concern	3 Conditions associated with decreased public concern	4 Applicability to ecological risk
Media attention	Much media attention	Little media attention	Directly applicable
Accident history	Major and sometimes minor accidents	No major or minor accidents	Applicability not clear
Equity	Inequitable distribution of risks and benefits	Equitable distribution of risks and benefits	How do various publics perceive equity issues between humans and non-humans?
Benefits	Unclear benefits	Clear benefits	Directly applicable. McDaniels et al. (1995) found negative correlation between perceived benefits to humans and perceived risk to nature.
Reversibility	Effects irreversible	Effects reversible	How well do various publics understand ecological recovery? How much or how little recovery is acceptable? What recovery times are acceptable?
Origin	Caused by human actions or failures	Caused by acts of nature or God	McDaniels et al. (1995).found less concern for ecological effects of natural disasters than for impacts of human activity.

Source (Columns 1-3): Covello et al. 1988.

As with human health and safety, disagreement and debate among experts can lead to misunderstanding on the part of the public. Disagreement and knowledge gaps are commonplace in science, but the public may not always discern the difference between honest scientific debate and confusion among experts (NRC 1989, Fischoff 1989). Debates on ecological risk may suffer not only from the current uncertainties in ecological risk assessment, but also from the apparent lack of knowledge about basic ecological concepts among the general public. If high-school students are any indication, there is little understanding of such concepts (Munson 1994; see Section IV, below). Kellert (1995) found little difference among age groups in their level of knowledge about nature. On specific issues, however, interested parties may show considerable knowledge (e.g., Reading et al. 1994), which parallels experience with human health risk issues. (See Section III, below, for further discussion of these studies.)

Communication of ecological risk-management options and decisions may face problems associated with lack of public knowledge about ecologically relevant laws and regulations or about the technical underpinnings of these requirements. For instance, the Clean Water Act has the goal of "fishable, swimmable waters," but not everyone may understand the relevance of toxicity testing with invertebrates to the achievement of that goal. And because economic value plays an important role in ecological risk management, differences of opinion about valuation of resources or priorities among competing resource-management approaches can lead to conflicts unlike those found in health-centered debates.

While some data exist indicating what the public knows or does not know about ecology, studies are needed concerning what information the public needs in order to participate effectively in debates over ecological issues. On one hand, it may be more important for concerned citizens to know about the detailed biology of a particular area or species that is the subject of a debate than to understand basic ecological theories. On the other hand, participants in larger-scale (regional, national, global) discussions about such issues as biodiversity might benefit from a general background in ecological principles to avoid being overwhelmed by the complexity of the myriad species and ecosystems at issue.

D. Summary

Communication about ecological issues differs in significant ways from communication about human health and safety, but the nearly two decades of research and practice in risk communication provides both the basic principles and the outline of research for ecological-issue communication to follow.

To begin with, communicators on ecological issues operate within the same social, political, and ethical framework as other communicators. Hence, the NRC definition of risk communication as "an interactive process of exchange of information and opinion" involving "multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reactions" applies equally well to communication about ecological issues. So too does the NRC's definition of success in terms of raising "the level of understanding of relevant issues or actions" and satisfying "those involved that they are adequately informed within the limits of available knowledge."

Differences emerge in the knowledge needed to make decisions on ecological issues and in the public perception of ecological issues compared to their perception of health/safety issues. A key difference, and a potential source of public debate, lies in the fact that ecological issues do not necessarily begin with agreement on what species or natural system is to be discussed. Ecological issues may also involve discussions concerning the appropriate level of organization (e.g., individual, population, community, ecosystem), types of effects (e.g., direct or indirect), and kinds of stressors (e.g., physical, chemical, biological) for study or management. Communicators may face the task of educating audiences about these and other technical matters, such as exposure and sensitivity, as a necessary first step in ensuring an informed debate.

Research in risk communication and perception offers some insight into how various concerned publics may evaluate information about ecological issues. That research also points to additional questions that could be pursued to understand more fully how the public perceives ecological issues. Following the lead of researchers studying perception of health and safety risks, such questions could be structured around the qualitative factors affecting public perception of ecological risks, including catastrophic potential, familiarity, reversibility, controllability, effects manifestation, and others. In a preliminary study of this type, McDaniels et al. (1995) constructed a similar taxonomy of factors applied to a measure of "risk to nature." Additional studies may reveal other aspects of public perception that expand upon or revise these categories.

Finally, although some research has been done concerning what people know about ecology, communicators could benefit from studies that elucidate what people need to know in order to participate fully in debates on ecological issues.

III. Attitudes toward nature and natural resources

Section II sought to show where communication on ecological issues may differ from health-related communication, based in part on differences in the risk assessment and management processes. Many of these differences derive from divergences of value, opinion, and perception among policy makers, managers, and the public with regard to ecological issues. Ujihara et al. (1991) assert that "[w]hile health risk communicators can take the public's health concerns for granted, ecological risk communicators cannot assume that the public will be as concerned about ecological threats." Some members of the public may be actively involved in debates over ecological issues and take a wide variety of positions, while others may indicate little concern. Differences in viewpoints may arise from perceptions of economic or other self-interest, focus of concern on personal health or safety risk, or attitudes toward nature and natural resources.

Western society has produced numerous philosophical systems that characterize the relationship between humanity and nature. These range from wholly anthropocentric notions of dominion over nature (e.g., White 1967, Worster 1993), to an "enlightened" anthropocentrism that recognizes resource limits and emphasizes conservation and management of natural resources (e.g., Ehrlich 1988), to holistic ("biocentric" or "ecocentric") views that see humanity as an integral part of nature, even subservient to it (e.g. Leopold 1949, Devall and Sessions 1985). This chapter examines a variety of world views with respect to nature and wildlife as expressed in public opinion studies.

A. Categorization of views of nature

Dunlap and Van Liere (1978) first created the New Environmental Paradigm (NEP) Scale as an attempt to measure the acceptance of broad environmental issues such as limits to growth, balance of nature, and anti-anthropocentrism. The NEP was a counterpoint to Pirages and Ehrlich's (1974) description of society's Dominant Social Paradigm (DSP). Part of the rationale for the NEP was that "implicit within environmentalism was a challenge to our fundamental views about nature and humans' relationship to it." (Dunlap and Van Liere, 1978)

Bengston (1993) describes the DSP as "emphasizing economic growth, control of nature, faith in science and technology, ample reserves of natural resources, the substitutability of resources, and a dominant role for experts in decision making" while the NEP is characterized by "sustainable development, harmony with nature, skepticism toward scientific and technological fixes, finite natural resources, limits to substitution, and a strong emphasis on public involvement in decision making."

In the initial study using this scale, Dunlap and Van Liere (1978) noted "a remarkable degree of acceptance of the NEP—not only among environmentalists, which was expected, but among the general public as well." In the years since then, Dunlap and his colleagues have found that the perspective represented by the NEP has expanded to include a broader ecological world view. This is reflected in a recent study by Dunlap et al. (1992) that sought to measure "possible changes in public endorsement of key elements of an ecological world view over time." These include:

- Reality of limits to growth,

- Anti-anthropocentrism,
- The fragility of nature's balance, and
- The possibility of an eco-crisis or ecological catastrophe.

Dunlap et al. conclude that "the overall pattern of increasing endorsement of the NEP . . . provides modest support for the view . . . that an ecological world view is gaining adherents."

Another approach to characterizing public opinion is to identify various categories of views with regard to specific subjects. Kellert (1993, 1995) has devised an attitudinal scale to measure attitudes toward wildlife and natural resources. The categories that emerge from his studies are as follows:

Naturalistic	Primary focus on an interest and affection for wildlife and the outdoors
Ecologistic	Primary concern for the environment as a system, for interrelationships between wildlife species and natural habitats
Humanistic	Primary interest and strong affection for individual animals such as pets or large wild animals with strong anthropomorphic association
Moralistic	Primary concern for the right and wrong treatment of animals, with strong opposition to presumed overexploitation and/or cruelty towards animals
Scientific	Primary interest in the physical attributes and biological functioning of animals
Aesthetic	Primary interest in the physical attractiveness and symbolic appeal of animals
Utilitarian	Primary interest in the practical value of animals, or in the subordination of animals for the practical benefit of people
Dominionistic	Primary interest in the mastery and control of animals
Negativistic	Primary orientation on avoidance of animals due to indifference, dislike, or fear

(Although Kellert specifically examined attitudes toward animals, the categories clearly apply more generally to views of nature.)

Findings from Kellert's studies generally concur with the conclusions of Dunlap et al. (1992). Kellert (1995) indicates his work suggests that "American attitudes toward natural resources and wildlife have become less utilitarian, negativistic, and dominionistic during the past twenty years and, more generally, during the course of this century." He cautions, however, "that these values (utilitarian and negativistic), as well as humanistic and moralistic perspectives, are [still] the most frequently encountered values of wildlife and natural resources in contemporary American society."

The implications of Dunlap's and Kellert's studies for communication on ecological issues deserve greater study. The findings of both suggest that a significant segment of the public is receptive to hearing about and discussing ecological issues. Kellert's work also indicates, however, that another important segment may be considerably less receptive. Additionally, receptiveness does not necessarily translate into knowledge and understanding. People holding a generally supportive ecological world view may still need considerable amounts of background information before they can deal effectively with specific ecological issues. Conversely, as the studies discussed below indicate, increased knowledge does not necessarily correlate with greater support for an ecological world view.

Steel et al. (1994) examined "the degree to which the public embraces differing values about federal forests nationally and regionally" by identifying the underlying philosophical values of both the national and Oregon publics. The authors define two orientations: biocentric, which "does not deny that human desires and human values are important but it places them in a larger, natural, or ecological context"; and anthropocentric. in which humans have "no ethical duties toward nature." They conclude that "both the national and Oregon publics tend to be more biocentric in orientation than anthropocentric." The national public was found to be more biocentric than the Oregon public. The likely reason for this finding is that the public of Oregon are more likely to depend on resource extraction for their livelihood. "Given the decline in timber industry employment and the stronger biocentric views of younger cohorts (and possibly future generations, given likely trends), we would expect the national and Oregon publics to become even more biocentric toward federal forests in the future."

Reading et al. (1994) studied regional attitudes toward nature, focusing on the Greater Yellowstone Ecosystem (GYE) within which "knowledge and attitudes toward the GYE were explored." An attitudinal scale was established to determine support for ecosystem management.

Ecosystem management:	Strong support for ecosystem management of the greater Yellowstone region and for the protection of wildlife and natural resources within the area.

Utilitarian:	Strong support for the direct utilization of natural resources with the GYE for human use.
Libertarian:	Strong support for individual rights and freedoms within the GYE.

The study found that the people surveyed were knowledgeable about nature and the importance of ecosystem management to protect the GYE. The level of knowledge, however, was not associated with strong support for ecosystem management. Rather, the study found widespread belief that greater ecosystem management would infringe on the individual rights of property owners as well as states' rights. The authors suggest that the region's historical association with resource exploitation accounts for these findings. This result is important for planning ecological risk communication programs: knowledge of ecology and nature does not automatically translate into support for protective action. As with health risk communication, many factors are weighed by members of the public when considering a public policy decision. In both the Oregon and GYE studies, economic concerns and a history of resource use played important roles in determining people's attitudes.

The categories used by different researchers are less important to communications practitioners than the fact that the populations studied were found to hold a wide range of world views concerning nature and natural resources. These findings support the idea of using the plural word "publics" when thinking about participants in discussions about ecological issues, rather than the unified word "public." When planning a communications approach, clearly the adage "Know your audience" continues to apply. Understanding that such a range of world views may exist within a single audience (or among several audiences) can lead to a communications strategy ensuring that all concerned participants feel that their voices are heard. Such understanding may also help communicators to identify types of information needed by different groups and to be prepared for differences in the way audience members may interpret information.

B. Social and demographic factors influencing views of nature

Many of the same authors who have categorized public opinion have also examined the various social and demographic factors that may account for their observations. Age, gender, race, social class, religion, ethnicity, and political beliefs are among the factors considered in these studies.

Van Liere and Dunlap (1980) found age to be an important determinant in measuring concern about environmental quality and incorporation of the ideals of the NEP. Numerous studies have indicated that younger people are more likely to be environmentally aware. One possible reason for this finding is that the young are less integrated into the DSP and therefore more ready to reject it. Steel et al. (1994) suggest that younger people have been more exposed to environmental education and at a younger age, thus allowing them to incorporate that education more readily into their world view. However, Kellert (1995) concludes from his studies of natural resource and wildlife issues that there is no significant differences among age groups in their knowledge of these issues. Kellert also questions whether this age effect is in fact an indication of "historic shifts in American society." It could, he argues, simply reflect "changes associated with progress through the normal life cycle." In other words, it may be that young people tend to be more idealistic but become more pragmatic as they age and assume more responsibilities that require compromise with ideals.

Gender appears to play some role in attitudes toward nature, but the relationship is complex. Van Liere and Dunlap (1980) report that "sex is not substantially associated with environmental concern. This conclusion should be viewed as tentative, however, as it is based on limited evidence." Steel et al. (1994) explain their finding that women have been found to have more biocentric attitudes than men as due to "socialization processes and the perception of moral dilemmas in terms of interpersonal relationships." In his studies, Kellert (1995) has observed that women have "stronger humanistic and moralistic concerns" for animals and nature while men "support utilization and dominance of nature." Males have "substantially greater knowledge of nature and ecologistic values . . . express stronger naturalistic values [and] tend to be less fearful of nature and wildlife."

Opinions differ as to how race affects environmental concern. Kellert (1995) finds that "African Americans generally express significantly less naturalistic, ecologistic, and moralistic environmental values than do European-Americans," while expressing "significantly greater support for the practical utilization and mastery of nature and wildlife." Caron (1989) disputes this view. Although "[b]lacks [have] often been characterized as unsupportive of environmental interests," Caron applied the NEP scale and "found moderate acceptance of a pro-environment perspective" among African Americans. Caron suggests that the reason for this discrepancy in results may lie in methodology as well as cultural issues:

> First, while most prior studies focused on specific issues such as air pollution, ours examined blacks' endorsement of a broad environmental orientation termed the new environmental paradigm. Second, it is likely that blacks evaluate specific environmental problems such as air pollution relative to other problems faced by racial minorities, such as discrimination and poverty.

Van Liere and Dunlap (1980) indicate that "environmental concern is positively associated with social class as indicated by education, income, and occupational prestige." They hypothesize that this might be explained by psychologist Abraham Maslow's theory of a hierarchy of needs: that environmental quality is a luxury that can be indulged only after more basic material needs are met. Steel et al. (1994) found that higher levels of formal education are associated with more biocentric values, suggesting that complex environmental issues are more easily understood with higher levels of formal education.

Typically, urban residents are found to be more environmentally concerned than rural residents. This could be because urban residents are exposed to more environmental deterioration while rural residents are more likely to have a utilitarian/extractive relationship with the land or share a culture with those that do (Van Liere and Dunlap 1980). Steel et al. (1994) suggest that the difference could be found in the increased information and educational opportunities that are found in urban areas. Kellert (1995) warns against this urban-rural distinction:

> Suburbanization of the American countryside, fostered by extensive transportation and communications technology, has converted many once insular rural communities into areas inhabited by many people pursuing an urban life style. As a consequence, dependence on land and natural resources for deriving a living has been found to be a better predictor of environmental values than simply the population of one's town of residence.

The factors of religion and ethnicity have been less extensively studied. Kellert (1995) has found that "[f]requent participation in formal religious activities is often associated with strong utilitarian and dominionistic values, supporting the right of humans to dominate and exploit natural resources and being less inclined to endorse wildlife protection."

Not surprisingly, political orientation is an important factor in opinions about the environment, with liberals expressing more environmental concern than conservatives. Van Liere and Dunlap (1980) present three arguments for this finding: "1) environmental reforms counter interests of business and economics; 2) environmental regulations entail extension of government; and 3) environmental reform requires innovative action." Steel et al. (1994) have also argued that environmental issues "cut across traditional ideological cleavages." They suggest that a better distinction is between post-materialists and materialist values with the post-materialist concerned "less with economic growth and security issues than it is with [Maslow's] 'higher order' values such as love for the aesthetic qualities of the environment."

The practical implications of these analyses for communicators are likely to be quite limited, given the tentative nature of most conclusions. It would be premature at best to assume that younger audiences, for example, are more likely to be interested and involved in ecological issues, or that men are less concerned about the environment than women. Until more definitive information is available, communicators will do best by evaluating the information needs and attitudes of the particular publics that they are trying to reach.

C. Other factors

An important determinant in environmental concern is what ecological component is at issue. According to Reading et al. (1994), "People ranked species with direct, consumptive benefits to humans, higher than other species. Of these other species, relatively well-known and attractive species were preferred over less charismatic species." Kellert (1995) has found that individual animals evoke more concern than plants; and plants more so than concepts such as ecosystems. Positive and negative biases toward, and familiarity with, certain organisms and environments affect decisions about what to study and what to protect. A recent (unpublished) analysis of Superfund ecological risk assessments showed that site reports cited aquatic environments more often than terrestrial ones, animals more often than plants, vertebrates more often than invertebrates.

D. Temporal trends in public attitudes toward nature

The studies cited indicate that a significant shift in attitudes, in favor of stronger support for environmental issues, has occurred over the last 25 years. This trend, however, in not uniform throughout the country, but is influenced by the regionality and heterogeneity of the United States. Social and demographic factors such as age, education, and type of job all play a role in determining the extent of this attitude shift.

Debate continues as to what degree environmental concern has permeated American society. A major factor in this uncertainty is methodological. Kellert has primarily measured attitudes toward wildlife, Dunlap and his colleagues have tried to assess overall environmental world views, and Steel et al. focused on a biocentric-anthropocentric dichotomy. Although these typologies are reasonably representative of approaches to this subject, they are by no means the only ones. Generalizing from all of these different research aims and methodologies into one definitive trend is risky at best.

If there has been an increase in support for environmental issues, this concern does not necessarily translate to increasing support for specific actions of ecological risk management. The research on opinion and attitudes shows varying degrees of concern for the environment depending on the issue and numerous other factors, as discussed above, and suggests relatively less support for ecological issues that do not directly relate to human welfare.

Ecological issues are likely to continue competing with a broad array of other issues for the attention of most members of the public. Even among those who appear to be committed to support for the environment, this concern may be focused primarily on protection of human health and safety. For others, interest in ecological issues may be localized to nearby natural resources or global in scope to include such matters as climate change and tropical deforestation. Whether any of these interests or concerns effectively carries over into meaningful participation in a particular ecological issue will most likely depend on the communicator's understanding of individuals' and groups' specific needs and attitudes, and the communicator's ability to both provide information and hear others' ideas.

IV. Insights from related fields: Environmental education and alternative environmental dispute resolution

Unlike risk communication, focused on human health and safety, the subject of communication on ecological issues has not been recognized as a specific field of study as such. Rather, researchers and practitioners are addressing relevant topics in a variety of disciplines and organizational environments. This section briefly examines two such fields, environmental education and alternative environmental dispute resolution, for information that may be pertinent to understanding the process of communicating on ecological issues. In both cases, relevant scholarly literature is extremely limited, but review of these few sources may suggest areas of further study.

A. Environmental education

For this review, an extensive search was conducted for journal articles and books concerning education of the public on ecology and related topics. Most of the literature was found to focus on classroom education; little appears to be published concerning education of the public about these same issues. This may be due to a traditional focus on school systems for educational research, including the availability of government funding for such studies. The National Environmental Education Act of 1990 addresses the needs of elementary, secondary, and post-secondary students while not mentioning the need for educating the general public. The focus of the Act is on developing environmental professionals. Public education efforts outside the schools, such as those conducted by conservation and environmental organizations, appear less likely to be discussed in the scholarly literature, perhaps because funds and personnel are not available to do the necessary evaluations or other studies appropriate for publication in such journals.

No literature was found concerning the general public's understanding of ecological concepts. However, Munson's (1994) study of high school students suggests that such concepts are poorly understood. Students did not understand the basics of what an ecosystem is and how it functions. In particular, they did not realize the connections between organisms other than direct connections (e.g., food chains). This lack of knowledge could increase the difficulty of communicating about indirect effects of stressors and related issues. However, Munson found not simply lack of understanding but significant misunderstanding of ecological concepts. He suggests that education is needed to address misconceptions that people already have of ecological ideas rather than "simply filling the apparent void of knowledge for the individual student." In his view, educators will need to present students with "experiences that encourage them to abandon their misconceptions in favor of scientifically acceptable conceptions." Munson goes on to state the importance of understanding students' prior knowledge and how this will affect "their interpretation of the world and development of additional knowledge."

Two papers focus on the need for education for reasons that go beyond increasing the public's knowledge. Fox (1995) urges scientists to engage in public environmental education to develop an "ecologically oriented world view." He believes that social change must come from a "bottom-up" approach (education) rather than "top-down" (e.g., legislation). Public education, in Fox's view, is in keeping with "the spirit of democratic institutions." The goal of education, then, is to allow legislation to express environmental values of the people, rather than impose them on the people. Gomez Pompa and Kaus (1992) see a need for education as a means for addressing environmental inequities. In particular, they feel that "the perspectives of the rural populations are missing in our concept of conservation. Many environmental education programs are strongly biased by elitist urban perceptions of the environment and issues of the urban world." They advocate an emphasis on local communities as sources of information on particular ecosystems and on the effects of conservation activities.

Two papers were found that describe efforts to educate certain segments of the public on ecological issues. Mullins and Neuhauser (1991) are concerned with involving communities in biosphere reserves. Westphal and Halverson (1986) seek to assess the long-term effects of environmental education.

Mullins and Neuhauser propose a strategy "based on the premise that public education (the right of the public to know) and public participation (the right of the public to be involved) support social cohesion and economic well-being within any community." Their approach includes identifying issues (e.g. threats to the reserves), identifying stakeholders, and building an environmental ethic. This third point echoes Fox's argument for an "ecological world view." The authors emphasize the need to "encourage biosphere-reserve communities to establish clear education objectives that are culturally, environmentally, and economically appropriate" In order to accomplish this, they assert, an ethic must be developed that deals with the cultural norms and economic reality of a population and how environmental ideals can be rooted in this pre-existing combination.

Westphal and Halverson studied the effects of a workshop program focusing on environmental education. Their results indicated that there was partial success in "greater citizen awareness and public participation." Specifically, the public became more involved in public decision making processes that involved water quality of Lake Michigan. Westphal and Halverson also suggested criteria for analyzing effectiveness. "Providing goals and objectives that can be quantitatively assessed throughout a program is the first step toward improving the content of environmental education programs designed to encourage citizen participation." Educational programs must be set up in such a way that they can be effectively assessed to see if the audience is comprehending and incorporating the messages that are being relayed.

The limited information available in the scholarly literature offers little in the way of specifics for communication practitioners concerning ecological issues. If Munson's observations of high school students hold true for the general public, communicators should be prepared to provide considerable background material on basic ecological terminology and concepts to prospective audiences if appropriate to the issue at hand. On the other hand, it may be more important for participants in an ecological debate to be informed about the detailed biology of the ecosystem(s), species, or effect(s) that are the subject of the communication. Fox's emphasis on education as a means of reinforcing democratic institutions is in keeping with the spirit of the NRC's discussion of risk communication as part of the democratic process.

Westphal and Halverson's suggestions about evaluation point to the need for more studies of public education programs. Various non-school-based education programs, including those conducted by non-profit organizations and state or federal natural resource agencies, should be examined and evaluated for their effectiveness. Specific educational strategies and techniques should be reviewed to determine what works well and what does not and why. In the absence of quantitative data, a case-study approach could elucidate examples of different types of educational efforts and produce qualitative assessments of their value for other educational and communications programs.

In conducting such case studies, it will be important to distinguish between the goals that the educators themselves might have had and those that an agency communicator might have. For example, an educator at a wildlife refuge might develop a program to inform visitors about the animals and plants in the refuge, so that they understand and appreciate what they are seeing when they visit. An agency communicator, on the other hand, might design a program to obtain greater and more informed public participation in a decision on how to manage the preserve. Strategies and specific methods in these two efforts could differ considerably, as might the specific audiences that the two programs were designed to reach. Nonetheless, the agency communicator could benefit from the experience of the educator, since some of the same information might need to be communicated, and audiences who had been exposed to material from the education program might be more receptive to communications concerning public participation. These kinds of linkages need to be made explicit when evaluating education approaches for their applicability to communication programs.

B. Alternative environmental dispute resolution

Alternative dispute resolution (ADR) describes a part of the environmental decision-making process that grew out of dissatisfaction with traditional, more adversarial approaches of litigation, administrative procedure, and the political process. According to its proponents, ADR approaches—such as mediated negotiation, joint problem solving and policy dialogue groups—provide a means for the various stakeholders to meet and reach mutually acceptable resolutions to the issues in dispute. The purpose of this brief review is to indicate possible areas where communicators on ecological issues might learn from the experience of ADR practitioners.

It is important to emphasize that ADR and communication have different, albeit related, objectives. ADR is a decision-making process whose goal is consensus among participants. Communication is a process of sharing information on facts, opinions, values, and feelings, with the goal of increasing understanding of the issues under discussion. No consensus or general agreement is necessary for a communication to be judged a success, nor is a decision a necessary outcome. However, the means by which ADR achieves consensus may provide some useful insight into certain aspects of the communication process.

ADR originated from an amalgam of approaches that had been previously used in several professions (Bingham 1986). Lawyers practice a form of ADR in settlement processes; rather than go to court, attorneys often negotiate a settlement between would-be litigants. Planners also utilize ADR techniques through the solicitation and facilitation of public participation into local planning decisions. Perhaps the best known ADR method is mediation, which for decades has been used to resolve labor/management disputes. In the 1960s, mediators began adapting their techniques to community disputes (Bingham 1986). This new application brought with it new problems, such as unequal power among participants, many parties to the dispute instead of the traditional two (e.g., labor vs. management), and professional experts vs. laypersons. Such problems are common to risk communication as well (NRC 1989, Fischoff 1989).

1. What is ADR?

Drawing on years of dispute resolution research and experimentation, the literature describing and proposing ADR approaches to decision making offers advice to interested parties who wish to resolve disputes by means of negotiated consensus rather than the traditional adversarial forms of dispute resolution (Lake 1980, Bacow and Wheeler 1984, Susskind and Cruikshank 1987).

A general definition of an ADR process is one in which various stakeholders voluntarily come together to engage in a dialogue that may lead toward consensus in resolving a problem situation (Lake 1980, Bacow and Wheeler 1984, Bingham 1986, Amy 1987, Susskind and Cruikshank 1987). Another critical aspect of ADR is that it is intended to be non-adversarial. According to Amy (1987), the non-adversarial, participatory nature of environmental mediation accounts for its large success. Additionally, ADR is seen as a relatively short and inexpensive process, compared with traditional forms of dispute resolution. ADR approaches may or may not require professional mediators.

Bingham (1986) cites many types of environmental disputes as appropriate for ADR, including land use (e.g., hazardous waste facility siting, industrial site development, historic preservation, and wetland protection), natural resource management and use, and water issues. These are also the kinds of disputes that often involve ecological issues.

Crowfoot and Wondolleck (1990) point out that the ADR approach "requires the parties (sometimes with the help of a skilled and neutral [mediator]) to develop and agree upon a process for discussion and decision making." For example, participants must agree at the outset on what their roles and objectives are; how information will be exchanged; and how they will communicate the results of the process to their constituencies, regulators, and others. Participants must also agree on norms and rules for communication and behavior early in the process. Will experts have a role in the process? If all participants do not have the technical knowledge required to understand the discussion fully, how shall they be educated? Finally, participants must articulate how, if an agreement is made, they will be bound to comply.

2. Criteria for ADR success

Traditional methods of dispute resolution (and risk communication) sometimes encounter opposition that challenges the legitimacy of the decision. ADR attempts to address this problem by directly involving all of the stakeholders in the process. Participation by itself does not necessarily provide legitimacy, as in the notice-and-comment process provided federal law. The decision-making process itself must be perceived as legitimate. In addition to legitimacy, Susskind and Cruikshank (1987) suggest four benefits of ADR, which can also be seen as criteria for success. Three of these benefits, or criteria, that appear to be relevant to communication on ecological issues are fairness, wisdom, and stability. A fourth, efficiency, seems less appropriate to the communication process, and will not be discussed here.

Susskind and Cruikshank assert that "What counts most in evaluating fairness is the perceptions of the participants." They also advocate "plasticity," where the process goes wherever the participants take it. Rigid processes, they argue, are perceived more as forcing an outcome. To evaluating the fairness of an ADR process, they pose several questions:

- Was the process open to public scrutiny?
- Was everybody who wished to participate given the opportunity?
- Were all parties given access to technical information?
- Was everyone given the opportunity to express their views?
- Were the people involved accountable to constituencies they ostensibly represented?
- Were the means available whereby a due-process complaint could be heard at the conclusion of the negotiations?

All but the last of these questions could profitably be adapted to evaluating a communication effort.

Susskind and Cruikshank define a "wise settlement" as one that "contains the most relevant information." They assert that this is accomplished by ensuring the participation of all sides so as to minimize the risk of being wrong. Presence in an ADR setting is not enough; participants must engage in dialogue. This is also the goal of a successful communication.

A third benefit of ADR is the stability of the decision that is made. Even if the process is perceived as fair, efficient, and wise, it is not useful if results of the agreement cannot be sustained. For Susskind and Cruikshank, feasibility is key to the stability of an agreement. The feasibility criterion provides a "reality check" as to what can be accomplished in negotiation. Communicators concerned with ecological issues also must be sure that the communication process, while allowing all reasonable views to be heard, remains grounded in the biological and other realities: what species or habitats are affected, what realistic options are available, what the consequences of proposed actions (or no action) are, etc.

3. Two examples of alternative dispute resolution

ADR encompasses a broad array of methods, including (among others) arbitration, mediated negotiation, information exchange/joint problem solving, and policy dialogue groups. The latter two approaches appear most relevant to communicators on ecological issues. This section describes both methods through the use of brief case studies.

Information exchanges and joint problem solving dialogues began in the mid-1970s. ACCORD Associates, a public policy research institute, led the way by serving as facilitator in several applications of this approach, intended to bring "individuals and groups together early in a planning or decision making process to exchange information and improve their ability to anticipate and resolve potential conflicts before a polarized dispute occurred." (Bingham 1986) The Delta County Quality of Life Project (Bingham 1986) offers an example of a successful joint problem solving effort.

In the mid-1970s, Delta County in Colorado was experiencing rapid economic and population growth. The county, with a population of 19,000, did not have a professional administrative or planning staff, but it did have a voluntary planning commission. In January 1977, the Delta County Chapter of the League of Women Voters contacted ACCORD for guidance on preparing a county development plan. The League's primary concerns were that development appeared to be causing increased polarization in the county, and that this might stand in the way of planning.

After preliminary meetings with community leaders, ACCORD and the Delta County League of Women Voters decided to co-sponsor a one-day workshop to encourage a dialogue on the issues and to develop a joint vision of the county's future. To design the workshop, ACCORD and the League established a steering committee, open to all county residents. Twenty people showed up to the first steering committee meeting to lay the foundation for what became known as the "Quality of Life" Workshop.

Over the next year, the steering committee worked to gain sponsorship for the project. Failure to rapidly obtain widespread support and sponsorship demonstrated to the committee that a lack of trust already existed among the county's residents. Nevertheless, the committee eventually received endorsements from 29 organizations and the Delta County Commissioners. As this support grew, such other organizations as banks, the Chamber of Commerce, and various service clubs also contributed to the project.

On March 8, 1978 the workshop was held. Support for it had expanded throughout the county. From the 270 workshop attendees a wide variety of ideas emerged regarding the county's future. When the workshop concluded, three ideas emerged to address the problems associated with rapid growth:

- Begin a county planning process,
- Improve education in the county, and
- Increase citizen involvement in decision making.

Over the next year the committee reconvened to implement the suggestions from the workshop. During that period the committee worked with the school board to acquire community input and support for a bond issue that had previously failed. The committee also developed a policy, with community input, on a county-wide land-use plan.

Bingham (1986) recounts the genesis of **policy dialogue groups** in Washington D.C. in the 1970s. The purpose of these groups was to bring together business leaders and environmental leaders for constructive dialogue on issues that appeared to divide them. Later, in an expansion of the concept, industries with opposing viewpoints on policy issues where brought together in dialogue groups to discuss their differences. Participants in most early policy dialogues served not as representatives of a particular corporate interest, but as respected individuals representing key points of view.

Another version of policy dialogue groups is regulatory negotiation. In these negotiations stakeholders (environmental groups, industry, and government) engage in dialogues focusing on each party's interest with regard to a specific proposed regulation. If agreement can be reached on the proposed regulation through this process, the likelihood of litigation is reduced.

In practice, policy dialogue groups work similarly to mediation. Participants may or may not choose a third-party mediator. An effort is made to invite all stakeholders, although in early policy dialogue groups regulators were not invited to the table in the hope that environmental leaders and industry representatives would speak more freely. Nelson (1990) cites the Common Ground Consensus Project as an example of such a group.

The Common Ground Consensus Project was originally the idea of the Illinois Environmental Council (IEC). For years the IEC had battled with the state's agricultural interests on the legislative front. Legislation repeatedly had been defeated doe to lack of agreement between these two groups. In 1982 an IEC board member proposed the Common Ground Consensus Project (CGCP), which was intended to bring farmers and environmentalists together to iron out differences, foster an environment of trust, and (they hoped) achieve agreement on some points.

After receiving a foundation grant to cover some of the costs, the CGCP organized a task force that included representatives from environmental and agricultural organizations. Together these representatives identified issues that could be supported by both interests. The task force decided to meet every other month and invited a wide range of interests to participate. All organizations chosen were politically active in both agricultural and environmental issues and had no association with the state government. Every organization contacted agreed to send a representative to the CGCP task force.

A neutral, professional mediator was chosen to facilitate the task force meetings. During the first meeting, the mediator described his role as an independent voice who does not become involved in substantive issues, but may provide problem-solving tools. At the outset the facilitator encouraged the group to develop procedures to facilitate decision making and task completion. Other procedural details helped to foster group cooperation and develop a sense of trust among members.

Next the group worked to identify an agenda. The facilitator guided the group through brainstorming exercises, interest identification, issue clarification, and discussion using a collaborative group problem-solving methodology. In the first meeting, with the assistance of the facilitator, 36 issues were identified and grouped into six major topics.

During the second meeting the group developed problem definitions and an issue-selection procedure. Together the group decided to choose a single issue. This issue was to fit three criteria agreed upon by the group:

- Areas where the group can have the greatest impact,
- Areas where a dialogue can be constructed and action can be operationalized,
- Areas where the task force can reach agreement and have something concrete in time for the upcoming legislative session.

The task force chose to work on soil erosion and maintenance of soil productivity. Participants spent most of one session defining the problem, why it existed and identifying the key issues. A point of contention between environmentalists and farmers was mandatory regulations vs. voluntary compliance. After this exercise, it was evident that each side suffered from ignorance and misconceptions about what the other side thought. Despite this, the group rejected a proposal to develop separate position statements, preferring instead to continue with a consensus process.

Based on input provided by task force members, the staff research team developed soil erosion summary statements for the full task force to review. Of the twelve statements, four were agreed upon, four placed for revision, one was dropped and three were remanded to a subcommittee for clarification. The following meeting the problem definitions were agreed upon. For the next few months the task force worked on joint action plans. Despite occasional deadlocks, the group eventually agreed on four recommendations and three priorities for the legislature, which by the end of the session had passed two of the three proposals. Passage of the third in the next session was believed likely.

The Project continued for another year before disbanding. Summarizing, Nelson (1990) writes:

> Participants felt that consensus-based problem-solving builds trust because people can question assumptions; it avoids dominance by one organization; and it results in collaborative work that produces more sophisticated solutions than the "hall lobbying" of the legislative process. Two disadvantages participants mentioned were the slowness of the process and the difficult transition from a collaborative process to a competitive political process. . . . Common Ground did not produce action plans for the more adversarial legislature.

4. Implications for communication on ecological issues

As stated at the beginning of this section, ADR and communication have different objectives. ADR is focused as much on the outcome as on the process, while communication may be considered successful based on process alone. ADR is a collection of procedures for decision making; communication is an essential element in *any* decision-making process.

Despite these differences, the experience with ADR can offer some useful ideas to researchers and practitioners concerned with communication about ecological issues. Adapting criteria for success of ADR to evaluating communication efforts has already been discussed. Communicators might also learn new strategies from ADR for identifying stakeholders, building trust among participants, bridging gaps between technical experts and laypersons, and ensuring that all viewpoints are heard. Because many ADR cases involve issues around land and water use, facility siting, and natural resource management and utilization, there should be ample opportunity for relating ADR experience specifically to the kinds of questions that communicators on ecological issues are likely to ask.

Beyond the specific experience represented in ADR case studies, it may be useful to look on certain ADR scenarios as models for the communication process. If communication is seen as a multi-party exchange of information, a negotiation or consensus-building model might be helpful in reflecting the interactions that occur during such an exchange. In this model, stakeholders are seen as sources as well as recipients of information—on the detailed biology of a site or species, on the local or regional impact of management options, on the attitudes and values underlying positions concerning management options, etc. As both sources and recipients, stakeholders can "negotiate" what information they will share with others and what information they will accept as part of the debate. The communication process may become one of developing consensus among participants as to what information is needed, what (and whose) information is valid, and how information will be used in the decision-making process. If this model seems useful to communication researchers and practitioners, case studies from the ADR literature might shed some light on how disparate stakeholders come to agreement on the terms and conditions of a discussion.

V. Next steps for enhancing communication on ecological issues

This report has attempted to summarize a broad array of information, experience, and opinion from several disparate fields of study and practice as they pertain to communication about ecological issues. Given the historical (and current) emphasis in EPA on risk assessment and management, an examination of the linkages to risk communication (much of it developed by or for EPA) was a logical starting point. The general principles and philosophy underlying risk communication appear to hold for communication on ecological issues, and the approaches taken in risk-communication research suggest ways in which similar questions might be addressed with respect to ecological issues (e.g., McDaniels et al., 1995). Studies of public opinion and attitudes toward nature and natural resources provide valuable information for understanding the various publics that communicators face when addressing ecological concerns. The experience of practitioners in environmental education and alternative environmental dispute resolution could serve as useful case studies for understanding such processes as transmitting and receiving information, identifying stakeholders and their needs, and building consensus among participants.

Although insights from all of these fields are useful, there is also a large body of knowledge among communication practitioners who deal with ecological issues on a regular basis. Public discussions are replete with ecological subjects, from local zoning to global treaties. Many organizations have been communicating with the public about ecological issues for decades, including state and federal natural resource agencies, nonprofit environmental and conservation organizations, schools, print and broadcast media, and private industry. EPA itself has a wide range of experience with ecological issues (and communicating with the public about them), from setting standards and criteria to regulating pesticides, from remediating hazardous waste sites to protecting wetlands against development. As a first step toward understanding the particular strategies and methods needed for effective communication on ecological issues, researchers should identify and analyze a broad array of case studies, encompassing a significant number of organizational, process, and substantive types. These cases should be analyzed and evaluated for their similarities and differences, the principles that they may represent, and the types of controversies and approaches to resolution that occur. Researchers can use this information to formulate questions for further study, and practitioners can use the analysis to refine their own approaches to similar situations. It is important that the case studies be examined using standard bases of comparison, so that a systematic knowledge foundation can begin to be constructed.

The formal study of communication about ecological issues will evolve as case studies and other information begin to accumulate, and as researchers and practitioners share their knowledge and experience with each other to formulate new questions and approaches. This report could serve as a starting point for the development of a research agenda for this field of inquiry.

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Table 2: Summary of Case Studies

#	Case (Respondent)	Audience	Purpose	Approach/Process	Definition of Success
1	Potetintial impacts of oil and gas development on Lechuquilla Cave, NM (Yvonne Vallette, Region 6, 214-665-7446)	stakeholders (spelunkers, oil and gas developers, environmental groups, public)	solicit information on environmental and economic interests	part of EIS process	• increased agency knowledge • established process for protection
2	RCRA, site in NW Indiana with endangered species (Carol Alexander, Region 5, 312-886-4244)	general public and media	education (managing species)	fact sheet and press conference	• increased public understanding. • accurate media coverage.
3	Partnership with Nature Conservancy to demonstrate value of grassland ecosystem (Anonymous)	agencies and public	education (grasslands important)	focus groups to solicit feedback and used Governor's Assoc. to impart info	• feedback shaping policy
4	Massive fish kills resulting from use of azinphos, LA (Anne Barton, HQ, 703-305-7695)	stakeholders (media, sugar cane growers, sports and environmental groups)	eco communication	meetings with stakeholders	• people could relate to problem • took action to address risk
5	Environmental assessment for Southern Appalachia (Corey Berish, Region 4, 404-347-7109-6670)	stakeholders (local)	eco communication	part of EIS process	?
6	Planning in environmentally sensisitive areas (wetlands), GA (Jennifer Derby, Region 4, 404-347-3555-6781)	stakeholders (local agencies, planners, developers, property owners, environmental groups)	education (environmentally sensitive planning)	local government workshops	• got message to decision makers
7	LA Times series on farming and problems with environmental regulations (Virginia Donohue, Region 9, 415-744-1585)	media	education and explanation	meetings, fact sheet	• fair, more balanced article subsequently
8	Production of wetlands awareness poster (Kathleen Drake, Region 2, 212-637-3817)	public / educators	education (wetlands)	poster	• high volume of requests
9	Delaware Estuary Program's public outreach efforts (Deborah Freeman, Region 2, 212-637-3795)	public	education (recreational and other opportunities of estuary)	fact sheets, newsletters, maps, etc.	• requests for information • enhanced relations with related groups • increased attendance at public meetings

Table 2 (continued)

#	Case (Respondent)	Audience	Purpose	Approach/Process	Definition of Success
10	Production of pamphlet "Protecting the environment, whose job is it anyway?" (Joan Goodis, Region 3, 215-597-9343)	public	education (self-help ideas)	pamphlet	• wide distribution
11	Explaining to land management agencies the importance of EPA's regulatory authority (Gene Kersey, Region 8, 303-293-1693)	land management agencies	education (EPA's regulatory programs)	day-to-day open communication	• increasing inclusion of EPA in ecosystem management
12	Proecting Louisiana pine savannah through 404 Program (Bill Kirchner, Region 6, 214-665-8332)	COE, F & W, Nature Conservancy	establish agreement between agencies under 404 Program	interagency networking initiated by state agency	• first national wetlands mitigation bank
13	Conference on the adverse effects of pesticides, Corvalis, OR (Mike Marsh, Region 10, 206-553-2876)	scientists and agency biologists	eco communication (scientists and policy makers)	conference	• networking
14	Explaining ecological significance of NPDES aquatic toxicity testing to municipal water districts, Dallas, TX (Maria Martinez, Region 6, 214-665-2230)	local government	education (significance of testing to protect ecosystem)	variety of outreach (letters, conversations, meetings, etc.)	• conveyed significance
15	Explaining ecological assessment for Willow Run, Ipsilanti, MI (Mike McAteer, Region 5, 312-886-4663)	stakeholders (PRPs, media, town officials, public)	eco risk communication (especially need for priorities)	ecological risk assessment	• public accepted and did not challenge results and decisions
16	Public opposition to wetland development, CO (Paul McIver, Region 8, 303-293-1552)	stakeholders (developer, health department, USFWS, USCOE, public)	EPA requested COE revoke developer's permit	site visits, public meetings, etc.	• wildlife refuge created
17	Long Island sewage treatment and fish kills (Rosemary Monahan, Region 1, 617-565-3518)	stakeholders (local)	eco communication	citizen advisory committee, public meetings, etc.	• fish kills mobilized public concern and action
18	Watershed conference, Belleview, WA (Dan Phalen, Region 10, 206-553-6638)	stakeholders (farmers, loggers, fishers, scientists, agencies, developers)	education (watershed management/sustainable development)	conference with diverse audience	• 950 attendees, networking, etc.
19	Forest Plan for Pacific Northwest, WA/OR/CA (Dave Powers, Region 10, 503-326-6271)	stakeholders (local and national)	education (forest management and sustainable development)	public meetings, info materials, etc.	• enormous public input
20	Measuring the effects of xenobiotics in Chesapeake Bay (Donald Rodier, HQ)	stakeholders (public, local officials, media)	eco risk communication (eco risk assessments must be focussed)	workshop	• public agreed reasonable approach

Table 2 (continued)

#	Case (Respondent)	Audience	Purpose	Approach/Process	Definition of Success
21	Protecting shellfish beds from septic systems and cogeneration plant, Casco Bay (Ann Rodney, Region 1, 617-565-4424)	stakeholders (public, homeowners, DEP)	eco communication	fact sheets and various outreach activities	• community committed to protecting shellfish • public can do something to help
22	Reliability of sediment coring as barometer of PCB damage and ecological health of Hudson River (Ann Rychlenski, Region 2, 212-637-3672)	stakeholders (media, local public, officials, PRP, environmental groups)	education (reliability of sediment coring)	in-field demonstration, press release	• public observation
23	Creating cranberry bogs without permits, MA (Matt Scheisberg, Region 1, 617-565-4431)	stakeholders (industry, town officials, agricultural community, media)	eco communication (necessity of regulations and permits)	initiated enforcement actions while maintaining open lines of communication	• industry came into compliance and improved management
24	Leavenworth Prison diesel spill, Missouri River (Jeff Weaaatherford, Region 7, 913-551-7155)	stakeholders (public, local officials, media)	eco communication (assurance of proper prompt cleanup)	during mobilization and cleanup	• cleanup accomplished, people sensitized to oil spill problems
25	Wateshed monitoring partnership between Region II and public, Philadelphia (Peter Weber, Region 3, 215-597-4283)	students, teachers, conservationists, water company, officials, fishers	education (public involvement in monitoring)	citizens recruited and trained	• community involvement
26	Uncapped SF landfill SF as feeding ground for wildlife, Springettsbury, PA (Terri White, Region 3, 215-597-6925)	stakeholders (public, local officials, media)	eco communication	public meeting	• public satisfied and no longer concerned about issues
27	Destruction of Karner Blue butterfly habitat with siting of landfill by National Steel Corp., Indiana (Carol Witt-Smith, Region 5, 312-886-6146)	stakeholders (public, media, facility, special interest groups)	eco communication	public meetings under RCRA	• public happy to be informed and trusted EPA
28	Roofing shingles near wetlands at SF site, Tampa, FL (Merideth Anderson, Region 4, 404-347-3555-6581)	local officials	eco/hh risk communication	meetings between EPA lawyers and town officials	• shingles moved from wetland
29	Ground contamination from battery recycling facility at Cal West SF site, NM (Gerald Carney, Region 6, 214-665-6523)	Air force base managers	eco and health risk communication	part of ecological and health risk assessment	• managers understood issues • insightful questions and suggestions

Table 2 (continued)

#	Case (Respondent)	Audience	Purpose	Approach/Process	Definition of Success
30	Water and sediment contamination (not dioxin) are major ecological concerns at Sitka pulp mill (Bruce Duncan, Region 10, 206-553-8086)	stakeholders (pulp mill employees, mayor and city council, public)	eco and health risk communication	information materials (including video) and public meetings	• two-way communication able to get message across
31	SF river cleanup, Region 8 (Holly Fliniau, Region 8, 303-293-1822)	community	participatory eco and health risk communication	SF community relations, workshops, etc.	• pending
32	Methyl mercury contamination at ALCOA/Lavala Bay SF site, Point Comfort and Point Lavala, TX (Jon Rauscher, Region 6, 214-665-8513)	stakeholders (fishers, industry, officials, public, media, environmental groups,)	eco communication	SF community relations/outreach	• public concern and buy in

COMMUNICATING WITH THE PUBLIC ON ECOLOGICAL ISSUES: WORKSHOP REPORT

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CONTENTS

FIGURE

TABLES

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Our initial plenary session successfully set the stage for the discussions that followed. We wish to thank all of the speakers for their stimulating presentations: Gloria Bergquist, Bill Cooper, Branden Johnson, Larry Kapustka, Tony Maciorowski, Tim McDaniels, Naomi Paiss, and Jim Proctor. Thanks too to Lynn Desautels and Matt Sobel for their wrap-up comments at the end of the workshop.

Finally, we acknowledge with gratitude everyone who attended the workshop. Defining a field of inquiry is never an easy task, and this subject required that professionals from a wide variety of backgrounds listen to and understand each other's language and concepts. Over a period of only two days, a remarkable degree of cross-fertilization of ideas took place, which could not have happened without the openness and good will that everyone displayed at the meeting.

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October 10, 1995

COMMUNICATING WITH THE PUBLIC ON ECOLOGICAL ISSUES: WORKSHOP REPORT

I. WORKSHOP SUMMARY

A. Introduction

On May 24 and 25, 1995, Clark University convened a workshop in Washington, D.C., to discuss the process of communication between government agencies and the public about ecological issues. **Ecological issues** are those that involve primarily nature and natural resources, especially the potential adverse effects of human activities on natural systems. Communication is a multi-directional process, involving many different stakeholders, often representing a wide range of values, perceptions, educational backgrounds, and economic resources. Stakeholders can be information sources, receivers, and transmitters. The goal of the workshop was to provide recommendations for agency guidance, training, and research, so as to ensure that the debate on ecological issues is informed, reasoned, and equitable.

The workshop is part of a project conducted by the Center for Technology, Environment and Development (CENTED) of the George Perkins Marsh Institute at Clark, and funded by the U.S. Environmental Protection Agency's (EPA's) Office of Policy, Planning and Evaluation (OPPE), Office of Sustainable Communities and Ecosystems.

B. Background

EPA has in recent years focused increased attention on its role in assessing and managing ecological risks. While protection of human health remains a high priority, recognition is growing that natural resources also are threatened by pollution and physical alteration of the environment. Policy makers and the public are becoming more aware of (1) the value of natural resources and (2) the link between the well-being of the human population and the health of the natural world.

As part of its responsibility to make decisions and undertake other activities for protection of natural resources, EPA understands the importance of effective communications between the Agency and other stakeholders in the debates that take place. In the realm of human health and safety, a body of research and practice under the name of **risk communication** has developed over the last two decades, which has many insights that can inform the communication process on ecological issues. There are also, however, significant differences in the way human health and ecological issues are perceived, assessed, and managed that point to different approaches in communication. To help ensure that EPA communication practice reflects these differences and similarities, this workshop brought together experts from such fields as communications, ecology, social and behavioral sciences, public policy, and environmental ethics to discuss what is known about the subject, what should be included in training and guidance, and what research is needed.

C. "Risk" vs. "issues"

The original title of this project was "Research Priorities for Ecological Risk Communication," a specific reference to (1) the growing interest in, and development of, the practice of ecological risk assessment; and (2) the existing and evolving field of risk communication as it has grown up in the area of human health and safety. EPA and CENTED have since sought to broaden the reach of the project by using the term "ecological issues" rather than "ecological risk" in describing the subject matter of this workshop and of a related survey of EPA personnel. There are three main reasons for this shift in terminology:

- Within EPA, "risk" has become identified in many people's minds as being associated with the potentially harmful effects of toxic chemicals in the environment. Although EPA's Risk Assessment Forum has gone to considerable pains to demonstrate that risk has a broader meaning, the perception persists.

- There are activities both within EPA and elsewhere, such as various ecosystem management programs, that do not fit the standard risk assessment/risk management paradigm as exemplified by the EPA *Framework for Ecological Risk Assessment*. While the argument might be made that some form of risk evaluation still occurs in the decision-making process of such programs, the term and the framework are not necessarily accepted in those contexts.

- Federal and state agencies responsible for managing natural resources often have considerable expertise and experience in communicating with various publics about their activities and the reasons for taking certain management actions. These agencies either do not use the terms "risk," "risk assessment," and "risk communication," or may use them in different ways.

Hence, to cast the widest net for information and insight, the project (and the workshop) has been retitled "Communicating with the Public on Ecological Issues."

Nonetheless, the reader will notice many references to "risk" and "risk assessment" in this report. These references in part have to do with the experience of the participants, many of whom have studied and practiced risk assessment or risk communication in a regulatory setting for many years. They also reflect the fact that, despite the existence of other programs, EPA's mandates remain largely risk-driven, and risk assessment and risk communication will continue to be important parts of the Agency's activities for a long time to come. Finally, as EPA's Risk Assessment Forum attempted to show in the *Framework for Ecological Risk Assessment*, "risk" really is a broad term, not at all limited to toxicological investigation. The Forum adopted language such as "stressor" and "ecological component," rather than "chemical" and "receptor" to indicate the breadth of meaning that is possible within their framework. The reader is thus encouraged to give the widest interpretation possible to the terminology used in this report, and to accept that our intent at all times is to be inclusive.

D. Workshop participants

More than 40 people attended the two-day workshop. The group of participants was both multi-disciplinary and multi-sector in its composition. Disciplines represented included:

- Ecology, ecotoxicology, and ecological risk assessment;
- Communications, public affairs, and risk communication;
- Decision science and public policy;
- Geography, anthropology, and other social sciences; and
- Philosophy and ethics.

Institutions represented at the workshop included:

- EPA (OPPE, Office of Pesticide Programs, Office of Water, and Office of Research and Development);
- The U.S. Department of Agriculture (USDA Forest Service and Animal and Plant Health Inspection Service);
- The U.S. Fish and Wildlife Service;
- The National Science Foundation;
- The U.S. Department of Energy;
- State environmental and natural resource agencies (New Jersey, New York, and Pennsylvania);

- Environmental groups (Environmental Defense Fund, National Wildlife Federation, and World Wildlife Fund);
- Regulated entities (Water Environment Federation, American Forest and Paper Association, and Monsanto Corporation);
- Two environmental consulting companies; and
- Ten universities and one National Laboratory.

Appendix A lists the workshop participants and their affiliations.

E. Structure of the workshop

The workshop consisted of two plenary sessions, separated by meetings of four breakout groups. (See Agenda, Appendix B.) The initial plenary session, designed to set the tone of the workshop, began with a keynote address by Dr. William Cooper of Michigan State University and a member of the EPA Science Advisory Board. Participants then heard three background papers:

- "Ethics and Values in Ecological Controversies: The Case of Biodiversity Conservation in the Pacific Northwest," presented by James Proctor of the Department of Geography, University of California at Santa Barbara
- "Characterizing Perceptions of Ecological Risk," presented by Timothy McDaniels of the School of Planning, University of British Columbia
- "Survey of EPA Staff re: Communicating on Ecological Issues," presented by Dominic Golding of Clark University, Co-Investigator of this project

Following these presentations, a panel discussion took place, focusing on the needs and experiences of practitioners regarding communication. The panel included a risk communication researcher in a state environmental agency, public affairs directors for an industry association and an environmental organization, an ecological risk assessor from an environmental consulting firm, and an EPA scientist/manager. The panel consisted of:

- Gloria Bergquist, American Forest and Paper Association
- Branden Johnson, New Jersey Department of Environmental Protection
- Larry Kapustka, ecological planning & toxicology, inc.

- Tony Maciorowski, EPA Office of Pesticide Programs
- Naomi Paiss, National Wildlife Federation

The breakout groups formed the core of the workshop. Participants were divided approximately equally into four groups based on their expressed interest in the topic area. The topics for the groups are listed below, along with the group chair.

- Group 1: Ethics and values; C. Richard Cothern, OPPE
- Group 2: Scientists' and the public's perception of ecological issues; Charles Menzie, Menzie Cura Associates
- Group 3: Organizational aspects of the communication process; Roger Kasperson, Clark University
- Group 4: Characteristics of ecological issues affecting the communication process; Lawrence Slobodkin, State University of New York at Stony Brook

Under the direction of the breakout group chairs, each group was asked to:

- Summarize what is known about the topic, either from research or practical experience;
- Indicate key points about the topic that EPA should emphasize in training and providing guidance to Agency communicators; and
- Recommend priorities for research in the topic area to improve or enhance communication of ecological issues

Groups met the afternoon of May 24 and the morning of May 25. Some group chairs and other participants also held meetings and writing sessions on the evening of May 24. On the afternoon of May 25, the plenary session resumed with reports from each breakout group, along with discussion from the audience. The meeting concluded with wrap-up comments from Lynn Desautels of OPPE and Matthew Sobel, Dean of the Harriman School for Management and Policy at the State University of New York at Stony Brook. Group chairs met with Clark and EPA staff on the morning of May 26 to discuss common themes and the approach to reporting on the workshop.

F. Major themes

The workshop was not designed or intended to develop consensus among all participants and arrive at a common set of recommendations. Rather, each breakout group presented its findings and recommendations in plenary session, and participants raised questions and commented on the group reports. Nonetheless, several ideas common to two or more groups became apparent as the recommendations from each group were reviewed. These are grouped under five major themes: (1) policy; (2) risk assessment and communication processes; (3) terminology; (4) regulatory decision making and implementation; and (5) conveying technical aspects of ecological issues.

1. Policy

Two groups expressed a need for clear policy direction from the highest levels in EPA, which would emphasize the importance of ecological concerns in meeting the Agency's responsibilities. The Organizational group felt that EPA needs to state clearly that ecological issues are high priority for the Agency. This suggestion is similar to, although less far-reaching than, the EPA Science Advisory Board's recommendation in *Reducing Risk* that the Agency (1) specifically declare that EPA considers ecological risks as important as human health risks and (2) communicate to the public the importance of natural systems and their link to human health and welfare. At the same time, the Ethics and Values group pointed up the need to recognize the role of values in decisions related to ecological issues.

In her summary remarks, Lynn Desautels picked up on this latter point, suggesting that the role of values appears more important, complex, and challenging with ecological issues than with human health issues. With human health, she said, there is considerable agreement on what society values, but the relative importance of particular ecological outcomes, and of the species or systems to be protected, are likely to differ among various stakeholders in ecological controversies. In addition, as Bryan Norton pointed out, the values underlying particular stakeholder positions may be "under rocks"—partially or wholly unconscious rather than clearly understood.

The workshop groups made the following recommendations:

- Develop a specific policy establishing a high priority for ecological issues in EPA's organizational mission, and incorporating concern for ecological issues into broader policy making. (Group 3)

- Develop a policy statement regarding consideration of values and value judgments in ecologically related decision making. (Group 1)

2. Risk assessment and communication processes

Many participants in the group discussions felt that risk assessment and communication processes cannot and should not be separated from each other. Implicit in several comments and recommendations is that EPA's risk assessment paradigm and the *Framework for Ecological Risk Assessment* do not pay sufficient attention to communication as an integral part of the assessment process. The *Framework* does emphasize communication between risk assessors and risk managers, particularly at the Problem Formulation stage of the process, to ensure that the ecological risk assessment provides information relevant to the decisions that risk managers need to make. However, there is insufficient recognition in the *Framework* that defining the problem or issue to be studied is itself a public policy decision, which should include interaction and communication with a variety of interested parties.

Group 1 proposed a modified framework, with specific reference to eliciting information on values held by stakeholders, and with feedback loops incorporating information on changing conditions and changing values. In somewhat the same vein, Group 3 recognized that ecological issues often entail a much wider array of information sources than do health and safety issues. For example, individuals and local organizations often have more detailed information about specific sites and the species present than do government scientists or other officials. Equally important, the local and regional significance of particular natural systems can be a critical piece of information when designing studies and evaluating management options. Such information, which is inseparable from values, can best be obtained through dialogue with stakeholders. Finally, as the research in risk communication has found, stakeholders and the public perceive potential health and safety hazards according to a wide variety of factors, such as voluntariness, familiarity, dread, and equity, when determining the importance of those hazards. In his presentation to the workshop, Tim McDaniels described how respondents in his study perceive ecological risks and identified several factors that influence those perceptions. Understanding how individuals and groups perceive ecological issues, as well as how they receive and share information, could add a valuable perspective to problem formulation and study design, and could play an important role in formulating management options.

Recommendations in this category included the following:

- Revise/enlarge the *Framework* to show communication with stakeholders (not just risk managers) occurring throughout (not just after the risk assessment is completed). (Group 2)

- Change the risk assessment model to include values and ethics at the beginning of the process. (Group 1)

- Train scientists and communicators to think of communication as two-way and multi-way. (Group 2)

- Train communicators to include values, value judgments, and ethics in all aspects of describing and facilitating decision making. (Group 1)

- Adopt a wider view of information sources. (Group 3)

3. Terminology

As the discussion of "risk" and related terms in Section 2 above indicates, use of particular terminologies can provoke considerable controversy. Group 1 felt that "risk" should not be used in decision-making processes unless and until the values behind the word were clearly understood. Scientists in Group 4, on the other hand, were comfortable with a broad application of "risk," but were uncomfortable with terms such as "ecosystem health" and "integrity." Others, such as Lynn Desautels and Bryan Norton, believed that the latter terms are useful in a communications and policy context.

What emerges from these comments and conflicts is a need for care, clarity, and consistency in the use of language. Words do not, as Humpty Dumpty would have liked, mean whatever we wish them to mean. As the risk communication and perception literature has shown, scientists and statisticians may see "risk" in the very plain and (to them) simple terms of the probability of harm, but other citizens imbue the word with layers of other meanings, incorporating such matters as who is harmed (e.g., children or adults), whether the hazard is voluntarily or involuntarily encountered, etc. Tim McDaniels' presentation showed how the public perception of ecological risks can also be studied and characterized. Such differences in perception are also opportunities for communication. For example, ecologists do not necessarily see every change in nature as a problem or every problem as major. (See, for instance, the priorities identified by the Ecology group in *Reducing Risk*.) Conveying the idea that a particular issue may not be a cause for concern could be a challenge for communicators, especially if trust in the communicating institution is not strong.

Words used in communicating about ecological issues must work for all those involved. Terminology must not only be intellectually appealing and intuitively understood by decision makers and the public, but it must also be capable of being turned into something that is observable or measurable in the real world of birds, bugs, and bushes. If science is to inform public decisions, scientists must be able to conduct replicable studies or, if that is not possible, to develop testable models. If decision makers and the public are to make use of information from scientists, the concepts behind the studies must be accessible to a reasonable intelligence, however non-scientific and non-mathematical its training.

The discussions and recommendations in this area point to a larger, overarching need to develop methods for achieving agreement on terminology among diverse groups of stakeholders. Other recommendations in this category include the following:

- Avoid using poorly defined terminology (e.g., risk, ecosystem health, integrity) and jargon. (Groups 1, 3, and 4)

- Do not automatically label an ecological issue as a problem. (Group 4)

- Develop a common language accommodating scientific knowledge, lay understanding, and values. (Group 2)

4. Regulatory decision making and implementation

Just as communication is not fully separable from risk assessment, so too is it closely linked to the processes of making and implementing decisions. Communication is intended to support decision making, by explaining Agency options and decisions, obtaining information and viewpoints from affected parties, and ensuring that citizens' rights and concerns are honored. If the decision-making process itself constrains communication, no amount of communication skill or expertise can be expected to meet those objectives.

Discussion and recommendations from the groups focused on the need for greater flexibility in regulatory decision making, to reflect the characteristics of specific ecological issues. Management of ecological systems often involves tailoring intervention strategies to local circumstances and responding quickly to changes in physical and biological conditions. Not only can these conditions change, but the values and attitudes of stakeholders can also change. Such change could occur because of shifts in the economic situation, or as a result of communication or educational efforts, or other factors. Adaptive approaches to regulatory decision making would allow management to respond to these changes in creative and constructive ways.

Among the recommendations in this category are the following:

- Increase flexibility with respect to temporal and spatial scales of decision making, based on the most appropriate scales for each ecological issue. (Group 3)

- Establish deadlines that allow for consideration of values in decision making and implementation. (Group 1)

- Seek innovative forms of cooperation and partnerships in solving ecological problems. (Group 3)

5. Conveying technical aspects of ecological issues

As with many other technical fields, the science of ecology can appear enormously complex to a lay audience, or it can be oversimplified, possibly leading to erroneous conclusions about an issue. An additional challenge in communicating about ecological issues is to reach audiences who are used to personalizing concerns as a way of understanding them and setting priorities among the many issues that compete for public attention. Such personalization may lead to a focus on individual organisms or charismatic species, possibly at the expense of seeing the larger picture (e.g., the need to preserve habitat).

It is also important for ecologists, like other scientists, to be clear about the limits of their knowledge and their ability to predict outcomes of events (e.g., disturbances or management efforts.) Although ecological theories and general models provide valuable insight into the workings of natural systems, describing particular systems and their responses to disturbance or management requires a firm grounding in natural history—the detailed biology of each individual species and habitat under consideration.

The principles and findings of ecology are amenable to effective communication between ecologists and others, without losing sight of the science that led to those findings. Ecologists and communicators need to work together to find ways of conveying this information so that interested parties can participate fully in discussions about ecological issues. Key recommendations in this category are as follows:

- Communicate local implications of ecological issues. Focus on particular places where possible, both to help publics personalize the issue and to convey the "systems" aspects of ecology. (Group 4)

- Identify familiar themes that members of the public and scientists can relate to even though they stem from different conceptual frameworks (e.g., *preservation* of land for future generations and *preservation* of habitat). (Group 2)

- Frame discussions as much as possible in terms of the natural history of specific ecological components (species, habitats, etc.), rather than in terms of general principles or theories. (Group 4)

- Include relevant information on basic scientific principles and processes that may not be familiar to public, so that they can more readily understand the specific ecological issue. (Group 2)

G. Research priorities

A wide array of suggestions for future research emerged from the group discussions and final group reports. The topics listed below point to several concerns that occurred in a variety of contexts during the workshop. **Public understanding of ecological concepts and the scientific method** concerned many participants, especially (but not exclusively) scientists. The questions under this heading point up the need to know how the public perceives ecological issues before designing communication efforts so that information (including opinions, attitudes, beliefs, and values) is actively exchanged among participants. Examples of suggested research in this area include the following:

- How do people conceptualize and value ecological systems and their components? How do such conceptualization and valuing differ by gender, geographic region, cultural background, etc.?
- What is the nature and extent of public literacy on basic ecological concepts of importance to environmental protection?
- What does it mean to the lay public to have the weight of evidence suggest something? How can that perception be modified if it is not consistent with the scientific approach?
- On what geographic scales do people relate to ecological issues? How do attitudes toward particular species (e.g., "charismatic vs. "disgusting") affect how people relate to ecological issues?
- What mental models do members of the public use in thinking about specific issues and overarching issues?

Several research topics concerned **institutional knowledge and institutional change**. Questions focused on how well ecological information moves to, from, and within EPA, and how institutions such as EPA can shift (or add) focus toward ecological issues, especially in an environment of diminishing resources. Specific research topics included the following:

- What is the nature and extent of ecological knowledge among non-ecologists in EPA?
- How do EPA and ecologists outside EPA communicate?
- What are the various mental models used by environmental scientists and Agency personnel concerning opinions, beliefs, knowledge, and values?

- How does fundamental change occur in complex organizations? How do substantive institutional changes take place during downsizing?

- How does the culture of the organization (agency vs. corporation vs. NGO, command-and-control vs. participatory, hierarchical vs. egalitarian, etc.) affect the framing of and attention given to ecological issues?

Finally, a variety of questions suggested the need for **case studies, historical analyses, surveys, and other studies** to understand what knowledge is already present in the form of practical experience with communication, conflict management, and other related areas. Examination of these sources could lead to important insights for future communication efforts around ecological issues. Questions under this heading included the following:

- What do people learn from different kinds of communication approaches, messages, information, etc.?

- What can be learned from past ecological communication efforts in various institutions? What does and does not work in different contexts?

- How have different communities dealt with similar ecological problems?

- Does/should survey methodology (for studying public opinions and attitudes) differ for ecological issues compared to other environmental issues? If so, how should the methodology be changed to fit better?

The research topics listed above should not be taken as a definitive set of questions. The discussions about research at the workshop represent two days of effort at defining a new field of inquiry and, as such, need to be seen as a first step in an evolving process. As experience and knowledge accumulate from initial studies, new directions are certain to emerge that were not apparent during this workshop. It is important, too, to recognize that the suggestions put forward here reflect the collective experience of a limited number of people. Although considerable effort went into gaining representation from a wide variety of disciplines, organizations, and geographic areas, gaps inevitably occurred. As this report circulates, the authors expect and welcome discussion and debate over the workshop's findings and recommendations. Only through such a process can definitive research agendas develop and change.

H. Conclusions

Participants at the workshop generally agreed that the subject of communicating about ecological issues is both important and in need of study. From the discussions and recommendations, it is clear that practitioners in this area can benefit from much of the experience gained in risk communication concerning human health and safety, in applied environmental ethics, in organizational and public-policy studies, and in environmental education. The challenge is to identify those aspects that are directly applicable to ecological issues and those that do not apply. This clarification should lead in turn to new areas of research and training to ensure that the public is informed and participating in debates concerning nature and natural resources to the fullest extent possible.

II. GROUP REPORTS[1]

A. Ethics and values (Group 1)

1. Terminology concerns

Defining terms like "ethics" and "values" is both important and complex. Although there may be general agreement about what these two terms mean, it is not possible in this brief report to do provide thorough definitions. It is important to note, however, that the two concepts are neither mutually exclusive nor interchangeable.

Values can be defined as *attitudes, concerns, and preferences*, and **ethics** as *systematized values*. Ethics and values may further be categorized as cultural or situational. **Cultural** (or core) ethics and values can be thought of as those passed down by generations or generally held within a society; examples related to environmental issues include notions of justice, freedom, sanctity of life, and responsibility to future generations. **Situational** ethics and values may be considered those that change over a more finite time or that a particular segment of society embraces. In environmental debates, these could include such concepts as quality of life, rights pertaining to different groups (or species), monetary value, private property rights, local control, central authority, and legitimacy. Assigning any given value to one category or another can itself be controversial, since some may see the value as deeply rooted in history while others see it as more changeable.

Underlying value systems influence the definition of other terms in environmental debate. The terms "risk" and "communication" can each convey several meanings, which were the subject of considerable discussion within the group. Some group members disliked using the word "risk" because they felt that the term is too tied to public-health-related meanings that are not applicable to ecological issues. The term is also closely associated with

[1] These sections are based on the reports given by the group chairs during the plenary session, supplemented with notes made by the chairs and recorders during the sessions, and subsequently edited by the group chairs and the authors of this report. Workshop participants (and several individuals who were unable to attend) were then given the opportunity to comment on the draft report. Their suggestions for revision have been incorporated in this final report at the discretion of the principal authors. As such, the analyses and recommendations reflect primarily the views of the members of each group, modified by the additional comments and thoughts of the reviewers and final edits by the principal authors. Occasionally, individuals are mentioned by name in the text to give credit for specific ideas offered during the workshop.

threats from chemical contamination; physical and biological sources of harm to natural systems might not be recognized as "risks." Thus, these individuals argued, focusing on "risk" could constrain the scope of ecological controversies.

The definition of "communication" (and, more specifically, "risk communication") in environmental affairs has evolved considerably. Some of that historical variation was still evident within the group. Some participants focused on communication as a unilateral conveying of "risk messages." Others saw it as an educational process, while still others felt it should be an open dialogue among equals. In discussions, the group agreed that there is a difference between communication (which is multidirectional) and education (which may be more unidirectional). Both are important and need to be considered in the communication of ecological issues. The primary focus in designing a program for ecological communication should be on process rather than product and on how both communication and education affect the various publics involved.

Finally, the group recognized that specific issues and controversies will raise questions of definition that might seem technical but reflect the values of particular stakeholders. For example, if the desire is to return to "pristine" conditions, which "ago" is appropriate? Are conditions last year, a decade ago, a century ago, a millennium ago the appropriate ones to use as a benchmark?

2. Case study: Chesapeake Bay non-point source discharge contamination

In an effort to clarify the ethical and value issues involved in ecological controversies, the group chose to explore a specific case. Through examination of the particulars of a complex ecological question, the group sought to demonstrate how a taxonomy of values could be developed in a manner that would be meaningful to a regulatory agency such as EPA. The group selected the issue of contamination of Chesapeake Bay from non-point source discharges because it (1) concerned a problem occurring at a sufficiently large geographical scale, (2) involved numerous technical disciplines and consideration of several cultural groups, and (3) was both complex and controversial.

Due to fertilizer runoff from area farms, elevated levels of phosphorous and nitrogen are present in the Chesapeake Bay. Because of these elevated levels, algal blooms persist. These blooms then diminish the Bay's dissolved oxygen content. This lack of oxygen affects the flora and fauna that inhabit the Bay. By current standards, discharges from both point and non-point sources are well within the limits allowed by the Clean Water Act. According to experts, a voluntary reduction in the application of these chemicals is the best management strategy. Thus, the issue has arisen because ecological damage is occurring from discharges that are within regulatory limits to protect public health, and thus considered legal to discharge into the Bay.

As an agency with regulatory jurisdiction over the Chesapeake, several questions arise for EPA. What are the issues that could arise? Especially if the discharges are considered legal, what is the EPA's role? Is this education, communication, or advocacy? How should the Agency communicate these ecological concerns to the public? Should the communicator convince the public of ecological damage? Should she/he attempt to illustrate to the public the sources of the damage? Should the stakeholders make the choice? How should EPA identify or define who is (and who isn't) a stakeholder?

The group began by developing a partial list of categories of value (both cultural and situational) that could influence the communication process. These include:

- Tradeoffs
- Organizational structure of the community
- Recreation
- Economics
- Aesthetics
- Private property issues
- Subsistence (farming and fishing)
- Legitimacy of EPA's involvement
- Issues of "right" and "wrong"
- Differing, possibly opposing sets of assumptions among involved communities
- Distributional equity
- Responsibility
- Stewardship
- Costs vs. benefits
- Certainty in terms of efficacy

Such categories help to illustrate the possible breadth of values among the stakeholder groups involved in an ecological communication process. Awareness of the values underlying a debate or controversy is essential to maintaining a dynamic and continuous communication process. In this example, by taking stakeholders' values into consideration, a communicator might decide to:

- Tailor educational material to achieve greater understanding;

- Promote dialogue among contending groups;

- Identify "allies," change agents within the community, and areas of potential agreement or compromise; and

- Inform Agency personnel about the historical, cultural, or other bases for stakeholders' positions.

Understanding these values might also aid the decision-making process. For instance, understanding a community's values could help identify criteria that community members use in determining the acceptability of management options.

After completing this exercise, the group developed three statements of principle relating to ethics and values in ecological controversies:

- Ecological risk can usefully be defined as the potential for a reduction in value (where the specific values at issue may differ among stakeholders).

- A broad array of values is always possible, and various segments of the public may take "risk" to mean decline in different kinds of values.

- Means and ends are both important from the standpoint of ethics. Thus, while agencies must work toward management *outcomes* that are protective of the environment, communication strategies should emphasize *process* more than outcome to ensure that all concerned parties have an opportunity to be heard.

3. Values of different stakeholders: Perceptions and characteristics

Conflicts concerning ecological issues may arise when distinctions are made between objects of management and objects of values. Scientists, for example, may value particular species in certain ways while hunting, fishing, or hiking (e.g., what resource economists would characterize as "use values"—the recreational or food value of the species). When those same scientists are working as researchers or teachers or risk assessors, the species take on a different set of values (perhaps another form of use value—i.e., for use in understanding the natural world—or "intrinsic" or "existence" value—simply appreciating the fact that the species is part of nature). Placing a value on an ecological component (e.g., a species) may become more complicated when more than one community or social group is involved. Each group may regard the component based on a different set of values. Which one of these value systems should prevail? How should decision makers address such conflicts of values?

As another example, consider the question of scale. Ecological issues and impacts often present a variety of temporal (e.g., short-term, long-term, continuing) and spatial (e.g., local, regional, national) options for thinking about potential problems and solutions. Tradeoffs are necessary when choosing time and geographic scales for assessment and management, and the choices among these scales involves decisions based on values. Thus, while effects of environmental change occur at particular places, judgments about who should respond to such effects and in what manner could dictate the scale at which management takes place. Ecological assessors and communicators should be aware of what tradeoffs (and their associated values) are at issue at specific sites. Who makes these choices? What value systems are used to make the choices? When decisions need to be made, how can we be open to changing situations and to changing values and value systems?

One problem is to determine what the term "public" means. There are numerous publics and they have a variety of values and make different value judgments. The challenge is to provide real opportunities for opinion and information to be heard from the full range of affected parties representing differing value systems. Who defines which stakeholders and publics are the important ones? This process clearly is political, and needs to be debated and considered in an open forum.

4. New communication model for communicating ecological issues

A communication process should provide a forum where participants can explain and develop their values freely, and where no one group's values or interests dominate or control the exchange of information and ideas.

In most models describing the process of risk assessment, including the National Research Council's *Risk Assessment in the Federal Government: Managing the Process* (1983) and EPA's *Framework for Ecological Risk Assessment* (1992), communicating about risk or ecological issues is a kind of afterthought at the end of the process. The idea seems to be that agency scientists and others first analyze and characterize risks and then inform the public of the results. The group felt that this approach was backwards, and proposed instead a revised model that allows stakeholders' values to inform the process. The first step in this approach is to identify (1) the problem, (2) the perception of the problem, and (3) the dimensions of values and ethics involved in characterizing the problem, to determine what endpoints are important and why (see figure). In this step, stakeholders would be consulted as part of identifying the problem, to characterize such subjects as:

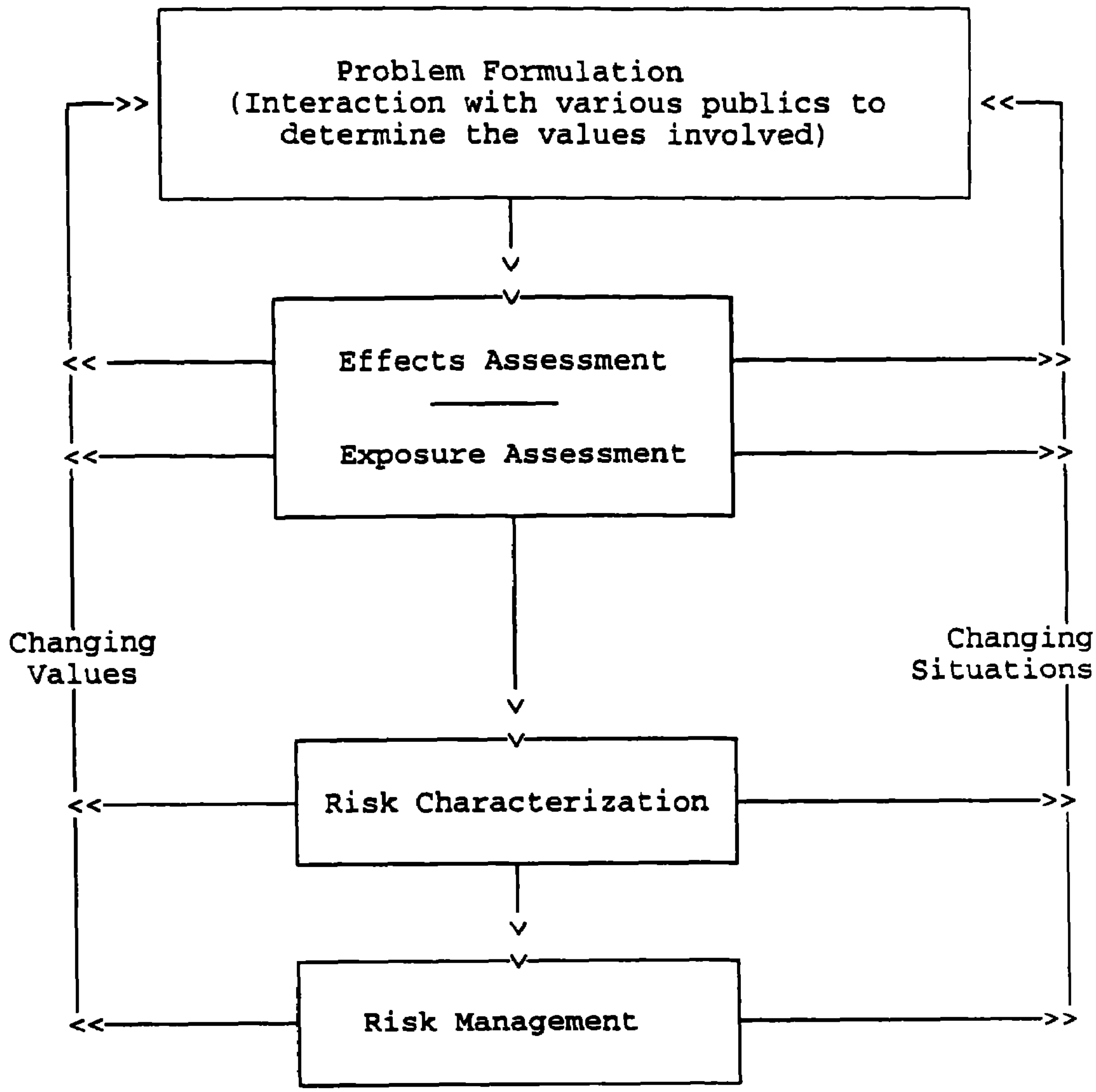
- Public perceptions and concerns,
- Scientists' perceptions,
- Legislation and administrative policy, and
- Environmental groups' and industry positions.

These inputs would be considered first before the risk is characterized. This step, in the revised model, would be followed by analysis (effects assessment and exposure assessment) and risk characterization. Value and ethical issues should be considered at every stage (as they are involved at every stage) and integrated into a risk management plan. Societal input needs to be included at every stage, thus including communication at every stage. Hence, communicating about ecological issues is a process that includes the analysis of ecological issues (rather than beginning after the analysis is complete) and is involved in every stage of assessment and management.

The revised model suggests to assessors and managers a process that is open to, and can incorporate, a diversity of opinions and values. A concern for fairness is central to such a process; the interchange among competing value systems should be an iterative process allowing the assessment and management to account for and adapt to the multitude of values and their changing nature. This process is consistent with current public-policy interest in local and community values. Following this model, agency officials should allow ample opportunity for community members to articulate their values in a constructive context. The model also exemplifies a broad view of ecological issues that includes perceptions, opinions, and values, along with the traditional technical definitions of risk and risk assessment.

This new perspective on the standard risk assessment model has several consequences. First and most important, the process begins with the determination of the interests and values involved. Second, information useful to the process includes both physical/biological data and information on values. Third, the model emphasizes both the initial status of such information and continual monitoring of changes in the situation (both physical/biological conditions and stakeholder values). Fourth, input to assessment is continuous and feeds back to all stages. Finally, this continual feedback of changing values and attitudes cannot continue forever in the assessment phase; it requires agencies to make explicit the criteria for deciding when there is sufficient agreement to select and implement management options.

Suggested Revised Assessment Model



5. Questions to aid the communication process

The foregoing discussion suggests ways of thinking about ecological issues, but not specific communication methods or techniques. The group identified several generic questions that may serve to clarify potential issues in an ecological controversy. These include the following:

- What is the objective of the program?
- How simple or complex is the ecological situation?
- Is the situation volatile, either socially or ecologically?
- What is/are the (temporal and spatial) scale(s) of interest?
- Is there a conflict or disagreement, either among experts or the public?
- What technical disciplines are involved?
- What are the cultural implications of the ecological issue?
- How do people's (individual or group) values inform the potential tradeoffs in management decisions? Who is involved in deciding what tradeoffs are to be made and what the basis for such tradeoffs should be?
- Do stakeholders view the issue in terms of voluntariness/involuntariness? How should such concerns be included in assessment and management decisions?
- How might values be understood and not assumed? Can community values be identified and characterized? Can stakeholder groups and their values be identified clearly?
- What kind of communication should take place and with whom?

Asking these questions in the context of a specific issue and with the proposed model of iteratively incorporating values and attitudes into assessment and management should allow communicators, assessors, and managers to identify and implement effective communication strategies that encourage full public participation.

6. Recommendations

The group made five recommendations:

(1) Change the risk assessment model used by EPA so that values and ethics are included at the beginning of the assessment process.

(2) Loosen deadlines for assessments to allow identification and inclusion of value and ethical issues in decisions.

(3) Do not use the word "risk" in assessment and management until the values involved (and their possible reductions) are identified.

(4) Train communicators to include values, value judgments, and ethical considerations in all aspects of describing and facilitating decision making.

(5) Develop an EPA policy statement regarding consideration of values and value judgments in ecologically related decision making, such as the following:

Values and value judgments are an integral part of environmental decision making and should be explicitly included for major regulations and decisions. Although part of everyday decisions, they become especially important when there is uncertainty in scientific and technical data and information.

B. Scientists' and the public's perception of ecological issues (Group 2)

In debates on ecological issues, as with other controversies involving the use and interpretation of scientific information, difficulties can arise from differences in how scientists and non-scientists approach such information. The group felt that communicators should seek to (1) understand the sources of disagreement and misunderstanding between scientists and non-scientists, and (2) create a process that tries to give fair weight to all viewpoints. (It is important to recognize that, in the end, the fairness of a communication effort can only be judged by those affected by the issue, not by the initiators of the communication.)

1. Initial thoughts

Although the above statement is appropriate, it is also important to note that the terms "scientists" and "non-scientists" do not represent single, homogeneous groups. Instead, terms such as "public" and "experts" represent very bumpy gradients of expertise, value systems, and other factors affecting how participants in a debate perceive the issues under discussion.

Given that communication on ecological issues occurs within a politics of expertise, it is important to recognize those gradients and develop an appreciation for legitimate differences in perceptions. While the group members felt that defining a common ground is critical, they recognized that doing so may not be easy (or even possible) because different people in a controversy are facing different decisions. For instance, an agency scientist might be determining whether available data support regulatory action on a particular product, while a citizen might be trying to decide whether to continue using the product.

From this initial consideration of perceptions, the group noted two elements of an effective communication that relate particularly to the question of differing perspectives. *Personal relevance* offers a limited role for science but can be a powerful influence on individuals' decisions regarding environmental issues (as in the example above concerning whether to use a certain product). *Efficacy* is the term the group used to describe the sense that people involved in the debate have a role in the decision-making process and can actually affect the outcome. Understanding these elements and how they affect other perceptions can be especially useful in defining a process or philosophy for communicating about ecological issues.

2. Differences in thinking about ecological issues

The group sought to describe in general terms how environmental scientists and the public differ in their thinking as to what is important in ecological issues. Discussing scientists' views was relatively straightforward, given the backgrounds of the participants. Ecologists are concerned about the *structure and function* of populations, communities, and ecosystems. Some may focus on keystone species as an important aspect of community structure and function.[2] *Ecological processes*, such as cycling of nutrients and material flow, are important considerations. *Habitats and their preservation* are key concerns, as are landscapes containing a variety of habitats. Scientists also think in terms of *temporal and spatial scales* that are appropriate to ecological components. The effects of exotic species on endemic ecological components, and other issues relating to *biodiversity* were also mentioned. Scientists recognize that their perceptions of a system may change as new information is developed.

The group believed that an understanding of what the general public sees as important is both highly variable and poorly known. Members of the group were able to relate their

[2] A keystone species is one on which much of the community's structure (number and distribution of species) depends. Removal or disturbance of such species is believed to cause a breakdown of the community. Not all ecologists subscribe to the concept of keystone species.

personal experiences with this question, but cautioned against generalizing from this limited perspective. They saw public perceptions of ecological issues as anthropocentric and situational (i.e., how people feel directly affected, or how an issue affects people's way of life). The group agreed that a host of influences could affect public perceptions, including cultural, recreational, aesthetic, and economic values, interests, and backgrounds. It also felt that public views are strongly affected by news media and headlines. Thus, what the public thinks is important can vary considerably over time.

The foregoing should not be taken to mean that the public does not care about ecological issues. The personal experiences of group participants suggest that members of the public care about and are educated about certain issues, especially those of local importance.

With regard to ecological components of concern to the public, the group felt that "charismatic" species get the most attention. Additionally, it appears that the public may be more interested in individuals than in populations, although it may also care about local populations of favored species. The group saw the public as personalizing its relationship to a particular ecological component, as "my" population, "my" landscape, etc. Participants also felt, however, that the public is increasingly familiar with habitats and habitat function, although again they saw this trend as varying widely. They believed that there is a strong appreciation for such aesthetic qualities as vistas and clarity of water.

3. Communication challenges

The group identified what it called communication challenges encountered by scientists as they attempt to communicate effectively with the public. This information is anecdotal; the group knew of no studies validating any of these observations and experiences. An important concern has to do with the nature of scientific debate. Scientists view disagreements among themselves differently from the way the public views such controversy. Scientists understand that they have different points of view, different levels and types of knowledge, and different amounts of faith they want to put into a set of data; they readily accept such differences as inherent to the process of scientific investigation. They expect that new information may resolve some differences or may lead to more differences. Scientists tend to recognize where the weight of evidence sits at any time and are able to balance the information to form a judgment about the item under study.

But these disagreements are heard differently by the public and may lead to some confusion, especially when amplified in the media. In some cases scientific expertise appears to cancel itself out; this may be seen by the public as a failure of science.

Variability and uncertainty are part of the scientific process but can pose difficulties in communication. One of the challenges is to simplify scientific detail so that the information can be understood by others. Scientific studies often involve large amounts of data, may include the use of complex models, and usually depend on an extensive knowledge base that underlies the immediate findings. If communication is to be effective, scientists provide information that simultaneously (1) can be understood by the lay public, (2) is perceived by concerned parties to be fair and balanced, and (3) does not leave out any elements that they consider essential.

The group felt that scientific agreement and decisions based on a sound technical footing do not receive the same coverage as the "hot" issues. As a result, the group believed that the role and value of science is under-appreciated. Members of the group indicated that a large number of environmental decisions occur based on sound science but do not receive media attention. They felt that scientific disagreement makes news, so the large amount of agreement is not reported.

Another aspect of the role of scientific debate is that scientists vary in their personal willingness to present their opinions based on how they perceive the strength of available data. In other words, some people are more willing to generalize than others. That willingness or unwillingness becomes a factor in determining how information is communicated and received.

Finally, scientists often pride themselves on their "objectivity" as they pursue their inquiries. Whether they are in fact objective is, of course, open to debate. But acting out of a belief in one's objectivity may create additional communication challenges, since lay audiences may interpret that behavior as distant and non-empathetic.

4. Key points EPA should consider in training and providing guidance to Agency communicators

The group believed that EPA needs to familiarize environmental scientists with the process of Problem Formulation in ecological risk assessment. In particular, they felt that training should emphasize the need for communication and dialogue with risk managers and stakeholders during this process to ensure that information needs are clearly understood. Training and guidance should convey certain essential elements of communication specifically aimed at transcending barriers of background and knowledge:

- Identify familiar themes that members of the public and scientists can relate to, even though the themes stem from different conceptual frameworks (e.g., *preservation* of land for future generations and *preservation* of habitat)

- Take into account the different levels of understanding and language among audiences when communicating broad messages.

- Try to develop and use a common language or working dialogue in situations where environmental scientists and stakeholders/managers are interacting. This language could be a mix of scientific and public terminology developed on a case-by-case basis.

- Discuss complicated environmental phenomena (e.g., nutrient cycles) in terms of things that are relevant to people and the decision.

- Take care to include background information on basic scientific principles and processes that relate to the issue under discussion. Scientists may consider such information to be common knowledge, but the public may not be familiar with it. Providing such background may help members of the public better understand the information related specifically to the issue at hand.

Training and guidance materials should also stress ways of achieving two-way or multi-way discourse. The group offered the following pointers as suggestions for inclusion in such materials:

- Allow initial meetings to take place without an agenda so that others feel free to set aspects of the eventual agenda, in a spirit of participatory democracy.

- Allow time for the formulation of the questions and problem to develop; do not try to fit the up-front process into an overly restrictive time schedule.

- Involve stakeholders, risk managers, and risk assessors early in the assessment/management process.

- Look for ways that stakeholders can be substantively involved in decisions (within the constraints of legal mandates), so that the communication process is seen as more than an opportunity to talk.

- Maintain communications throughout the process. Avoid communicating only during crisis situations.

- Be as inclusive as possible with regard to involving in a communication effort those individuals and groups who are likely to be affected by a decision. Consider especially the practical problems of reaching particular subcultures.

The group believed that training and guidance for environmental scientists is especially important. In the group's view, scientists should be encouraged and taught to:

- Initially be listeners at the Problem Formulation stage, to (1) understand better how the issues are framed from the standpoints of risk managers and various stakeholders, and (2) see how their own perspectives as scientists fit into a larger context of public discussion and decision making.

- Refrain from directing the flow of conversation at the early period of Problem Formulation, or viewing themselves as the ones with "the answers."

- Be aware of the big picture through internal communications with risk managers and others involved in the decision-making process.

- Be aware of the context and forum within which they are presenting information.

- Look for positive ways to help participants in a dialogue recognize misperceptions or misstatements of scientific information, such as identifying those parts of a statement or argument that are in keeping with scientific understanding and those that are not.

- Experience their own "blind spots" by discussing controversial personal experiences in which they have acted as lay persons.

- Be prepared for the presentation: know the audience, rehearse, understand the broader picture between scientist and manager.

5. Research needs

The group suggested that EPA develop a set of risk communication tips which, though not a research topic in itself, could involve analysis of case studies and other information to arrive at valid recommendations. While there are significant differences between risk communication for human health and communication about ecological issues, sufficient overlap exists to warrant codifying those elements that are demonstrably relevant. Other research recommendations include the following:

- Define the various mental models used by environmental scientists, agency personnel, and the public at large concerning opinions, beliefs, knowledge, and values related to ecological issues.

- Develop a better understanding of the factors that affect the public's perception of ecological issues using mental model methodology both for specific and overarching issues. Explore values, sense of stewardship of ecosystem, concepts of scale, variability.

- Explore how knowledge and values drive discussions related to ecological issues.

C. Organizational aspects (Group 3)

The group began by trying to identify the major issues that face any organization as it tries to grapple with the problem of communicating with various audiences about ecological issues. While the members of the group represented a diversity of organizations and offered illustrative examples from their own and other organizations, the focus of the conversation kept returning to EPA. Thus, the central question for the group became: As an organization, what does EPA have to do to strengthen its capability to communicate on ecological issues? In answer, the group identified a list of needed improvements in the internal structure of EPA, its external relations with other organizations and society in general, and its ecological communication and decision-making process. These improvements are listed in Table 1 and are explained in the remainder of this section.

Of course, many of these suggested improvements would apply to any organization (e.g., other government agencies, corporations, non-profit environmental groups, etc.), but they are aimed especially at EPA. If EPA is to communicate effectively about ecological issues, the group felt that it was absolutely essential that EPA develop a clear policy on ecological issues and accord ecological issues a clear and high priority in its organizational mission. Without this commitment the public will continue to doubt EPA's motives, and EPA staff and managers will feel like they are sailing a ship without a rudder. The Agency must strive to maintain consistency within and among sub-units and programs, including a consistent commitment to its mission.

The group felt that there is often a mismatch between the temporal and spatial scales of the problem at hand and the usual focus of the Agency. Often members of the public and environmental groups express concerns about issues that they consider predominantly local or regional. EPA needs to do a better job of "moving" among the various scales of the different problems and using local and regional resources and solutions as appropriate.

As an extension of this point the group felt that to be successful in this arena, any organization needs to be aware of its own strengths and limitations. For example, EPA has a good network of local and regional contacts through the regional offices, but communication between headquarters and the regional offices is often less than optimal. Similarly, EPA needs to recognize the limitations of the command-and-control approach to solving ecological problems and reach out to embrace new approaches in collaboration with non-profits and corporations.

Table 1. Necessary Organizational Improvements

Internal Structure

- Establish a high priority for ecological issues in organizational mission.
- Maintain consistency within and among sub-units and programs, to the extent allowed under legal mandates.
- Ensure agreement between temporal and spatial scales of organization and issues at hand.
- Be aware of internal organizational strengths and limitations.
- Develop a broad-based interdisciplinary (especially social science) capability.
- Integrate technical, social science, and communication elements of organization.

External Relations

- Do everything necessary to bolster and avoid losing public trust and organizational credibility.
- Move away from previous command-and-control regulatory regimes; seek novel forms of cooperation and partnerships.
- Be willing and open to sharing power with other organizations and the public, to the extent allowed by law.
- Be smart about the prevailing social climate.

Communication and Decision-Making Process

- Use limited resources strategically.
- Adopt a wider world view and set of information sources to allow identification of pertinent facts, attitudes, and values related to ecological issues.
- Develop good institutional listening and learning skills.
- Incorporate concern for ecological issues into broader policy making.
- Make ongoing and periodic evaluation of programs and activities an integral part of the decision-making process.
- Know your audiences, constituencies, and allies.
- Avoid jargon.

Given the complex nature of ecological communication, the group felt there was an urgent need for EPA to develop a much stronger interdisciplinary capability with a particular emphasis on the social sciences. Social scientists can serve an important function in the Agency, collecting and analyzing information on (1) other agencies and organizations with whom EPA must cooperate, and (2) the knowledge, beliefs, and attitudes of members of the different audiences with whom EPA must communicate. They can also play a crucial role in evaluating the successes and failures of past communications efforts.

Absent these data-gathering, analytical, and evaluative functions, future communications efforts are likely to fail, resulting in wasted resources and the further erosion of trust and credibility that may hamper other future efforts. All too often, communication programs are designed and implemented by technical and public-relations experts. The group believed that it was vital to integrate some significant social science expertise into this process to ensure that communication efforts are placed in the appropriate social context.

Institutional credibility and public trust are prerequisites for effective communication. Losing trust and credibility is easy, but regaining them once they are lost is extremely difficult. Unfortunately, there are no simple solutions. The message, therefore, is do everything possible to avoid losing trust and credibility in the first place and build on what levels of trust and credibility you already have. Adopting a clear agency mission and many of the other suggestions in Table 1 will help, but are no guarantee. Being smart about the social climate covers a lot of territory from being cognizant of very local issues and concerns to being savvy about larger trends in societal opinions and attitudes. Pushing for strong regulatory control over a problem that few people and organizations feel is important is a sure way to lose support, as has been amply demonstrated again and again (e.g., the Consumer Products Safety Commission's early efforts to regulate swimming pool slides). In the present anti-government and anti-regulation mood, it behooves EPA to move away from rigid command-and-control approaches of strict regulations toward novel ways to reach the same ends. These ways may involve greater cooperation and partnerships among past adversaries (regulators, environmental groups, and corporations).

Several members of the group felt that by lobbying so strongly to protect the spotted owl in the Pacific Northwest and appearing to ignore the plight of the loggers, environmentalists lost substantial local and national support. In the future, they felt it was necessary to look for new approaches that better balance competing interests and demands. On another front, increasingly the public is demanding greater participation in the communication and decision-making processes. Consequently, EPA will need to learn to be more open and more willing to share power where possible.

With reference to the communication and decision-making processes, the group felt that the Agency needs to make better strategic use of limited resources, going after the problems that are both important and most amenable to solutions. It is necessary to incorporate concern for ecological problems into broader policy making at all agencies, but at EPA in particular, because of its historic emphasis on protecting human health.. There is much to be done by social scientists and communications experts. The Agency needs to adopt a broader world view that is more sensitive to current social concerns, and this perspective should be informed by a broader set of informational sources.

As previous work on risk communication indicates, the Agency needs to avoid jargon and alienating technical or bureaucratic language, and get to know its audiences, constituencies, and allies better. To improve its communication most effectively, EPA needs to develop good institutional listening and learning skills.

After a vigorous and lengthy discussion of the broad range of issues, the group returned to a more detailed examination of some of the more fundamental problem areas or cross-cutting "meta-questions." The group began by trying to address the question: **How does an organization select ecological issues for attention and take action on them?** Unfortunately, the group was somewhat skeptical and less than optimistic about this process. In general, organizations like to work on issues where there is consensus within the organization about the nature and scope of the problem and possible solutions. Often, though certainly not always, organizations have to be goaded by outside events and "agitators" to move on particular issues—what the group called the "cattle prod hypothesis." While there has been some work previously on what kinds of events and agitation will move agencies, especially in the area of human health, the nature of the pressures and how such pressures operate in the case of ecological issues remains unclear. In general, regulatory agencies prefer to act on issues that offer the possibility of cost-effective solutions, and this trend is likely to become more pronounced over the next few years with the current emphasis on costs and benefits of regulations—an ominous note for the ecology community. Similarly, regulatory agencies tend to avoid problem areas that are not already identified in their mandates and budgets. In sum, the outlook is not good: it is going to be difficult to move the EPA, other government agencies, and corporations to deal with ecological issues that are viewed as new, risky ventures in which the payoffs are seen as long-term and somewhat nebulous.

The group examined the second "meta-question," **How do organizational factors affect effectiveness in communications with publics?** and concluded that in large part the answer comes down to values and commitment. To communicate effectively, EPA must clearly understand its constituencies and the target audiences—how they see the problem and what they see as an acceptable set of solutions. At the same time, as noted above, the Agency must understand candidly its own strengths and limitations in order to know what it can and cannot do and when it needs to seek the assistance of and collaboration with other groups. While the information-gathering and analysis functions noted above are important for understanding how stakeholders perceive particular ecological issues, good communication within the organization is needed so that all of this information is used effectively when the Agency needs to communicate its messages clearly and unambiguously to the public.

The overarching concern among group members, however, was the need for a strong Agency commitment to a mission encompassing ecological protection, with a clear strategy outlining how to achieve it. The mission should drive priorities and behavior, which means each sub-unit or program should be committed to the mission and moving toward a common goal, and ecological communication activities should reflect the core values embedded in the mission. If programs and communication activities drift too far from the mission then the Agency's constituencies, allies, and audiences will become disaffected and the staff persons will feel rudderless. Maintaining a strong, consistent commitment to a mission can be extremely difficult, especially since it is not easy to maintain a long-term perspective when much daily activity focuses on short-term "fire-fighting." An appreciation of these difficulties can only serve to emphasize the need to (1) develop a mission that is consistent with the core values of the Agency and not merely window dressing, and (2) embed short-term goals and activities within a long-term perspective and strategy. It also underscores the need for continual monitoring and evaluation to ensure programmatic activities and responses are consistent and stay within appropriate bounds or that the goals and objectives are reviewed and revised in a dynamic process reflecting feedback. Unfortunately, few organizations, whether agencies or corporations, are nimble enough to learn and adapt in this fashion.

Finally, there is a pervasive issue of what the real commitment of the institution is. Is it about looking good or is it about getting things done? How do you keep the organization focused on substantive goals, while the organization is trying to maintain its political and economic survival?

Reflecting on the list of issues and the two "meta-questions" above, the group asked: **How will the change to a greater ecological focus occur, especially given the particularly difficult institutional and social context?** For the foreseeable future, Congress appears hostile to regulation in general and environmental or ecological protection in particular. The public is often ignorant about ecological issues and ambivalent about ecological protection, but apparently in favor of a more limited role for government. Having dealt with some of the most severe, dramatic environmental problems (mass fish kills, rivers catching fire, etc.), makes dealing with the more pervasive but less dramatic problems (e.g., pesticide runoff, wetlands destruction, etc.) more difficult. Responsibility for dealing with ecological issues is extraordinarily fragmented among various agencies, corporations, and NGOs at a variety of spatial and temporal scales. Finally, with regard to EPA in particular, the group asked, where is the "champion" of this issue who will lead the sea change in the way that William Ruckelshaus led the charge for risk assessment and William Reilly promoted comparative risk assessment? Can change succeed in the absence of an EPA champion, given the many constraints?

The group identified a set of issues rather than answers in response to this question and the group's rather sober assessment of the problem setting. Rather than expecting this sea change to occur through a rational unfolding of the public policy process, it may be more helpful to look to the "garbage can" models of decision making. According to these models, problems come in to an organization and queue up for attention. Relative position in the queue, the nature of previous decisions, and the extant social, political, and legal context and will determine which problems are addressed when and how. Unfortunately, the position of ecological issues in the queue does not look promising and the group concluded that a top-down approach may not work at EPA or other federal agencies with responsibilities for these problems. Rewards and incentives clearly are going to have to play a major role in achieving the necessary changes in institutional culture. Such changes are difficult at the best of times, but they are especially difficult at a time of institutional downsizing and they are compounded by growing levels of resentment and distrust among career and political appointees. There is also considerable cynicism about the latest fads (e.g., the recent emphasis on Total Quality Management) and attempts to redirect the Agency to address issues of sustainable development and ecological protection could be viewed in the same light, especially given downsizing efforts and the general anti-regulatory and anti-government climate.

Before moving on to identify a communication strategy for EPA, the group identified two more **conundrums** that make dealing with ecological issues all the more difficult. Firstly, many ecological problems (e.g., loss of wetlands, habitat destruction) are intimately related to local land use, but there has never been any federal land-use policy. Immediately, therefore, there is a disjuncture among federal, state, and local agencies and their respective jurisdictions. Second, unlike health risk problems, there is seldom a single, identifiable villain in causing ecological damage—rather, we all appear to be the villains, if the issue is extended back to first causes such as consumption patterns. Obviously, communicating to the public about such complex matters will be a tough job for EPA. The Agency will have to build constituencies where they do not currently exist and develop a greater public awareness of and commitment to ecological protection. One way to help this process may be to link ecological and health concerns, since it appears to be easier to arouse public support on the latter than the former. EPA is going to have to seek strategic alliances with other agencies, corporations, and NGOs, since the solutions are beyond the capabilities of any one organization. Internally, the Agency will need to create greater linkages among the different programs and build much better capability for internal coordination and communications. In particular, EPA will have to reach out to other organizations that operate at local, state, and regional scales, and this effort may require substantial internal restructuring of the Agency so that it is better able to work with and serve local constituencies.

The group moved on to propose a set of **research recommendations**. These include the need for a set of case studies that examine how fundamental change occurs in complex organizations (corporations, NGOs, and government agencies). These case studies should be designed and conducted by several well-known organizational sociologists. Second, it would be helpful to examine the special problems of creating institutional changes during downsizing. Third, how does the culture of the organization (agency vs. corporation vs. NGO; command-and-control; hierarchical vs. egalitarian; etc.) affect the framing of and attention given to ecological issues? Fourth, there is a great need to examine past ecological communication efforts in various institutions to learn what does and does not work in different contexts, and understanding how those institutions define and judge success. Finally, it would be valuable to have a set of comparative studies of how different communities have dealt with similar ecological problems.

Finally, the group developed a set of **recommendations on guidance and training**. EPA needs to develop, strengthen and empower a cadre of integrative thinkers to examine more broadly than usual the organizational and other issues that arise in addressing ecological problems. The Agency needs to develop an authentic ecological and social science capability through appropriate hiring and the interdisciplinary training of managers and staff in ecology and social science. The lack of interdisciplinary capabilities stems in part from the lack of interdisciplinary training at universities, which need to pay greater attention to and give credit for interdisciplinary teaching and research. Training courses on ecological communication need to be developed, building on the existing courses on risk assessment and risk communication. Finally, a task force on ecological communications would seem to be a very worthwhile next step, and the task force might begin with a thorough cross-institutional study of current activities and programs to get a better sense of what other agencies are doing in this area.

D. Characteristics of ecological issues affecting the communication process (Group 4)

1. Ecologists and communicating ecology: Seven themes

This group shifted the emphasis from one of considering inherent characteristics of ecological issues to that of thinking about what ecologists know and how they convey what they know to non-ecologists. In that context, the group formulated seven "themes" (here grouped together in three major categories) that could form the basis for talking to ecologists about communication and to communicators about ecology. These themes are listed in Table 2 and explained in the text.

Table 2. Seven Themes on Communication about Ecology

Characterization of ecological issues

1. If you don't understand a term (e.g., ecosystem health, integrity, complexity), don't teach it to others! Corollary: If it is neither interesting nor useful, forget it!

2. It is important that ecological issues are not automatically defined as problems.

Extent and limitations of ecological knowledge and understanding

3. There is no one scale inherently most important in dealing with ecological issues. The scales at which each issue is best addressed need to be identified on a case-by-case basis.

4. Ecologists can predict changes in the likelihood of an event, even if the initial situation is known only within broad limits. Not all questions can be answered with equal accuracy. The relative degree of certainty needs to be clearly stated.

5. Ecologists understand that the systems they study are complex. Even so, they should be able to communicate what needs to be known clearly and simply, including what is well understood and what is not understood. If the information submitted by scientists does not pass this test, it should be redone.

6. On most technical issues, experts are likely to hold legitimate differences of opinion. Weight-of-evidence arguments guide decisions and should be used to evaluate individual inconsistencies or uncertainty.

Effective communication of ecological information

7. Often, humans relate best to ecological and related issues on a local scale. Thus, local implications need to be communicated in order for many messages about ecological issues to be effective. It is often relatively easy to communicate ecological issues in terms of particular places as a way of personalizing those issues.

Theme 1: *If you don't understand a term (e.g., ecosystem health, integrity, complexity), don't teach it to others! Corollary: If it is neither interesting nor useful, forget it!*

Many words easily convey positive or negative feelings, so it is tempting (and sometimes useful) to try to use such words when describing the current or predicted state of an ecological component. If the goal of a proposed action or program can be described as protecting, restoring, or improving the "health" or "integrity" of an ecosystem, perhaps by preserving or enhancing its "complexity" or "diversity," the action or program will give the illusion of being both good and comprehensible to an audience that might not fully understand the technical details. Similarly, if the ecosystem is described as (or predicted to be) "degraded," "damaged," or "impaired" in the absence of protective or corrective action, such words communicate the need to take such action.

The difficulty with using words such as those in quotation marks above is that, while the **values** represented by such words are clear, the precise **meanings** often are not. This problem does not mean that such terms should never be used. It does mean that scientists who use them should be careful to define exactly what a term means and why it is being used.

John Denne reported that, in his experience, the Forest Service had not encountered significant opposition to the term "forest health." However, another group member indicated that, in arguments with forestry officials, it was impossible to agree on a definition of "ecosystem health": proposed definitions included net primary productivity, species diversity, resemblance to forests before Europeans arrived here, etc. Two members expressed the opinion that ecosystem health is not a scientific concept subject to examination by traditional scientific methods.

Despite these concerns, Lynn Desautels, in her wrap-up comments for the plenary, voiced the hope that terms such as ecosystem health could be retained because of their communication value. She emphasized the need to include a precise contextual definition when using such terms, and to be aware of conflicting definitions and the values underlying alternative definitions.

Clearly, use of these terms carries a considerable risk of conflict along with the potential benefit of communicating certain values. One group member commented that ecologists should, in general, state ecological issues as much as possible in terms of natural history—the detailed biology of each individual species and habitat under consideration. If larger, overarching terms such as "health" are then also kept close to the natural history of a species or location of concern, the likelihood of misunderstanding or conflict may be reduced.

Theme 2: *It is important that ecological issues are not automatically defined as problems.*

This statement seems self-evident, but in practice it may be difficult to implement. Seeing the difference between problems and non-problems, and communicating it, are not always easy. Ecologists do not necessarily see every change in nature as a problem or every problem as major. Conveying the idea that a particular issue may not be a cause for concern could be a challenge for communicators, especially if trust in the communicating institution is not strong.

Factors such as natural variability and natural recovery might lead a knowledgeable person to conclude either that no adverse effect has occurred, or that no corrective action is needed. If the geographic area affected by a stressor is small, a site manager might conclude that the costs of protection or restoration are not justified by the benefits. In these cases and others, however, the decision might be the opposite if the cumulative effects of "small" events were determined to have larger consequences.

EPA's statutory authority often determines what constitutes a "problem" for the Agency to address, irrespective of the issue's relative importance to ecological protection. Ecosystem approaches to environmental protection, such as EPA's watershed ecological risk assessment initiative, are welcome attempts to identify realistic priorities among numerous competing concerns.

Theme 3: *There is no one scale inherently most important in dealing with ecological issues. The scales at which each issue is best addressed need to be identified on a case-by-case basis.*

The term "scale" should be taken broadly in the context of this statement to include the spatial dimension (e.g., the size of a contaminated area), the magnitude of the event (e.g., the percentage mortality in a population), the time frame involved (e.g., how long for a habitat to recover from a pollution event), and the ecological level of organization (individual organism, population, community, ecosystem) at issue.

In our discussions, one member suggested that there is generally an inverse relationship between spatial scale and immediacy. That is, the smaller the scale the more immediate the consequences of a disturbance. Conversely, larger geographic scales are generally associated with longer delays in observing effects of a stressor. This person proposed a general statement that small-scale events are obvious but not urgent, while large-scale changes are urgent but not locally obvious.

Although the above sounds like conventional wisdom, it was not difficult to think of exceptions, such as ozone depletion and the incidence of skin cancer (albeit a health example). Another important reason to avoid uncritically relying on this generalization is that it runs the risk of failing to recognize cumulative effects of small-scale events. It was also in this context that the importance of communicating local implications was first discussed. Hence, the statement emphasizes the need to evaluate each ecological issue's scale(s) on the basis of detailed knowledge about potentially affected species and habitats.

Theme 4. *Ecologists can predict changes in the likelihood of an event, even if the initial situation is known only within broad limits. Not all questions can be answered with equal accuracy. The relative degree of certainty needs to be clearly stated.*

For communication on ecological issues to be useful, participants need to understand both the capabilities and limitations of ecology to answer questions that might arise. In general, ecologists understand that they are trying to describe or predict events in complex, integrated systems of which they have incomplete knowledge. Nonetheless, basic understanding of how such systems work should allow us to say whether the probability of an adverse (or positive) effect's occurrence will increase or decrease as a result of some stressor or action. We may not be able to say anything about the magnitude of the event, or its duration, or what will happen next. The second point in the above statement serves to remind us that not only is our knowledge of natural systems incomplete, it is also unevenly distributed. This limitation applies both within and among particular environments. Thus, for example, much more information is available about the toxic effects of chemicals on aquatic species than on terrestrial species, but considerable variation exists in the quantity and quality of information on aquatic species. As usual, the farther we move from our base of knowledge, the more speculative our answers must become. It is important that ecologists acknowledge this fact when they offer expert judgments and predictions.

Theme 5: *Ecologists understand that the systems they study are complex. Even so, they should be able to communicate what needs to be known clearly and simply, including what is well understood and what is not understood. If the information submitted by scientists does not pass this test, it should be redone.*

This statement is the complement to Theme 4, which focused on limitations of knowledge. In Theme 5, we emphasize that what is known is amenable to clear communication. Non-ecologists should not accept assertions that an issue or system is too complex to explain in terms that they can grasp. Ecologists should not assume that lay audiences cannot understand important facts about ecological systems. A key phrase in the above statement is "what needs to be known," which can only be defined in the context of the decision that must be made, the values of stakeholders, and the legal and resource constraints under which information can be collected and disseminated. Ecologists, managers, and communicators need to be as clear as possible with each other about what information is needed for a decision or a communication. If that is done, communicating such information in a form that non-ecologists can understand and use should always be possible.

Theme 6. *On most technical issues, experts are likely to hold legitimate differences of opinion. Weight-of-evidence arguments guide decisions and should be used to evaluate individual inconsistencies or uncertainty.*

There was considerable debate in the group over this theme, particularly concerning scientific consensus. Some members felt that, for many issues, the scientific community is in general agreement, and that outlying opinions could in effect be discounted. Others objected to the term "consensus" because it connotes unanimity and because the history of science is replete with examples of outlying theories or opinions that later became widely accepted. The group also recognized, however, that decisions need to be made based on generally accepted norms for evaluating conflicting scientific views. Terms such as "general agreement" and "scientists' collective judgment" were offered, but none completely captured the concept. This theme was motivated in part by the concern on the part of some group members that *any* opposing view, however isolated it might be from the "mainstream" scientific community, might be given equal credence and thus hamper effective communication or decision making. In short, there is a general principle (which, like all such principles, is not absolutely valid all the time) that an outlandish opinion is best ignored when making serious decisions.

Theme 7: *Often, humans relate best to ecological and related issues on a local scale. Thus, local implications need to be communicated in order for many messages about ecological issues to be effective. It is often relatively easy to communicate ecological issues in terms of particular places as a way of personalizing those issues.*

As mentioned, this arose first in the discussion about scale. In the presentation to the plenary, the first two sentences of this theme were stated as part of the theme on scale (Theme 3 in this report). The matter of "localism" as a communication question surfaced many times in the workshop, including the report on the survey of EPA staff.

The discussions in Group 4 focused not only on geographic scale but also on the question of public identification with an ecological issue. The group recognized the problems that can arise from identification of an issue with individual organisms, especially members of "charismatic" species. Such identification often fails to convey the importance of systems in ecology.

Steve Hamburg suggested that a focus on "place" offers a useful alternative to identification with individuals or particular species. Place refers not to local jurisdictions but to specific environments (which may cross political boundaries), such as forests, wetland, watersheds, etc. He pointed out that at the same time that national environmental groups are struggling to maintain membership, local land trust organizations are burgeoning. Focusing on place provides opportunities to convey system concepts and the need to maintain ecosystem structure and function. It allows for dissolving distinctions between charismatic and "disgusting" organisms, since often the emphasis in solving a particular problem must be on how the system works as a whole rather than the preservation of favored parts. "Disgusting" organisms are often of great ecological importance. For example, worms and molds are vital to the persistence of most terrestrial ecological characteristics.

2. Research questions

Group members individually prepared suggestions for research on topics related to the themes described above. The group briefly discussed these topics but did not develop a single set of priorities. Below are listed some of the questions raised by Group 4 members.

- How do people conceptualize and value ecological systems and their components? How do such conceptualization and valuing differ by gender, geographic region, cultural background, etc.?

- What is the nature and extent of public literacy on basic ecological concepts of importance to environmental protection?

- What does it mean to the lay public to have the weight of evidence suggest something? How can that perception be modified if it is not consistent with the scientific approach?

- On what geographic scales do people relate to ecological issues? How do attitudes toward particular species (e.g., "charismatic vs. "disgusting") affect how people relate to ecological issues?

- What is the nature and extent of ecological knowledge among non-ecologists in EPA?

- How do EPA and ecologists outside EPA communicate?

- Does/should survey methodology (for studying public opinions and attitudes) differ for ecological issues compared to other environmental issues? If so, how should the methodology be changed to fit better?

III. CONCLUSION

This workshop was part of a three-element project that Clark conducted for EPA to define the questions that should be addressed in developing a field of study and practice concerning communication on ecological issues. A review of literature on related fields showed that many basic principles from risk communication, historically focused on human health and safety, are applicable to communication about ecological issues. So too are findings on public opinions and attitudes about nature and natural resources. A survey of EPA personnel, primarily in the regional offices, demonstrated that the Agency already carries out a variety of communication efforts concerning ecological issues, and that many individuals have considerable experience with and insight on the subject. Many of the recommendations put forward in this workshop parallel the ideas identified in these other two parts of the project.

All three components of the project also pointed up important differences between human health and ecological issues. Where health and safety issues often lead to personalization of risk information (even when it may not be appropriate), ecological issues may suffer from inattention due to a lack of personalization. Ecological effects of stressors may be harder to understand than health effects, especially if the effects are indirect and delayed. And different groups of people may use very different sets of values to determine the importance of ecological issues in comparison to health issues. Public attention to ecological issues, public and agency understanding of ecological systems, and policy-level support for addressing ecological concerns were among the subjects that appear most important to enhancing communication on ecological issues.

One theme that occurred often in individuals' and groups' suggestion was to conduct case studies on communication about ecological issues. Many participants recognized that a rich history of experience resides in federal and state natural resource agencies, nonprofit conservation and educational organizations, and in parts of EPA itself. Organized and analyzed systematically, these case studies could be used to help develop training and guidance materials and to identify questions for future research. Studies should include a representative set of cases from the full array of organizations that have undertaken activities related to ecological research, education, and management. Pending available funding, Clark hopes to carry out a first round of case studies in the near future.

APPENDIX A. WORKSHOP PARTICIPANTS

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APPENDIX B. AGENDA

May 24:

8:00-8:30	Coffee and registration	
8:30-8:40	Welcome	Michael Dover, Clark University
8:40-9:00	Welcome	Angela Nugent, EPA/OPPE
9:00-9:20	Keynote address	Bill Cooper, Michigan State University
9:20-9:40	Background paper: Ethics and Values in Ecological Controversies: The Case of Biodiversity Conservation in the Pacific Northwest	Jim Proctor, University of California, Santa Barbara
9:40-10:00	Background paper: Characterizing Perceptions of Ecological Risk	Tim McDaniels, University of British Columbia
10:00-10:20	Background paper: Survey of EPA Staff re: Communicating on Ecological Issues	Dominic Golding, Clark University
10:20-10:50	Break	
10:50-12:00	Panel discussion with audience participation	Michael Dover, moderator Gloria Bergquist, American Forest & Paper Association Branden Johnson, NJ Dept. of Environmental Protection Larry Kapustka, ecological planning & toxicology, inc. Tony Maciorowski, EPA Office of Pesticide Programs Naomi Paiss, National Wildlife Federation
12:00-1:30	Lunch	

1:30-2:15	Introduction of topics for breakout groups	Michael Dover, moderator Rick Cothern, EPA Roger Kasperson, Clark Univ. Charles Menzie, Menzie-Cura Associates Larry Slobodkin, SUNY at Stony Brook
2:30-5:00	Breakout group meetings	
May 25:		
8:00-10:00	Breakout group meetings	
10:00-10:30	Break	
10:30-12:15	Breakout group meetings	
12:15-1:30	Lunch	
1:30-3:00	Breakout group reports	Dominic Golding, moderator
3:00-3:15	Break	
3:15-4:30	Plenary discussion	Michael Dover, moderator
4:30-5:00	Wrap-up	Lynn Desautels, EPA/OPPE Matt Sobel, SUNY at Stony Brook
5:00	Adjourn	
May 26:		
8:00-12:00 (with break)	Discussion of report format and content	Workshop conveners, breakout chairs, recorders, others

Appendix D

FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT

Appendix E

EPA RISK CHARACTERIZATION PROGRAM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D C 20460

MAR 2 1 1995

MEMORANDUM

SUBJECT: EPA Risk Characterization Program

TO: Assistant Administrators
Associate Administrators
Regional Administrators
General Counsel
Inspector General

EPA has achieved significant pollution reduction over the past 20 years, but the challenges we face now are very different from those of the past. Many more people are aware of environmental issues today than in the past and their level of sophistication and interest in understanding these issues continues to increase. We now work with a populace which is not only interested in knowing what EPA thinks about a particular issue, but also how we come to our conclusions.

More and more key stakeholders in environmental issues want enough information to allow them to independently assess and make judgments about the significance of environmental risks and the reasonableness of our risk reduction actions. If we are to succeed and build our credibility and stature as a leader in environmental protection for the next century, EPA must be responsive and resolve to more openly and fully communicate to the public the complexities and challenges of environmental decisionmaking in the face of scientific uncertainty.

As the issues we face become more complex, people both inside and outside of EPA must better understand the basis for our decisions, as well as our confidence in the data, the science policy judgments we have made, and the uncertainty in the information base. In order to achieve this better understanding, we must improve the way in which we characterize and communicate environmental risk. We must embrace certain fundamental values so that we may begin the process of changing the way in which we interact with each other, the public, and key stakeholders on environmental risk issues. I need your help to ensure that these values are embraced and that we change the way we do business.

First, we must adopt as values **transparency** in our decisionmaking process and **clarity** in communication with each other and the public regarding environmental risk and the uncertainties associated with our assessments of environmental risk. This means that we must fully, openly, and clearly characterize risks. In doing so, we will disclose the scientific analyses, uncertainties, assumptions, and science policies which underlie our decisions as they are made throughout the risk assessment and risk management processes. I want to be sure that key science policy issues are identified as such during the risk assessment process, that policymakers are fully aware and engaged in the selection of science policy options, and that their choices and the rationale for those choices are clearly articulated and visible in our communications about environmental risk.

I understand that some may be concerned about additional challenges and disputes. I expect that we will see more challenges, particularly at first. However, I strongly believe that making this change to a more open decisionmaking process will lead to more meaningful public participation, better information for decisionmaking, improved decisions, and more public support and respect for EPA positions and decisions. There is value in sharing with others the complexities and challenges we face in making decisions in the face of uncertainty. I view making this change as essential to the long term success of this Agency.

Clarity in communication also means that we will strive to help the public put environmental risk in the proper perspective when we take risk management actions. We must meet this challenge and find legitimate ways to help the public better comprehend the relative significance of environmental risks.

Second, because **transparency** in decisionmaking and **clarity** in communication will likely lead to more outside questioning of our assumptions and science policies, we must be more vigilant about ensuring that our core assumptions and science policies are **consistent** and comparable across programs, well grounded in science, and that they fall within a "zone of **reasonableness**."

While I believe that the American public expects us to err on the side of protection in the face of scientific uncertainty, I do not want our assessments to be unrealistically conservative. We cannot lead the fight for environmental protection into the next century unless we use common sense in all we do.

These core values of transparency, clarity, consistency, and reasonableness need to guide each of us in our day-to-day work; from the toxicologist reviewing the individual cancer study, to the exposure and risk assessors, to the risk manager, and through to the ultimate decisionmaker. I recognize that issuing this memo will not by itself result in any change. You need to believe in the importance of this change and convey your beliefs to your managers and staff through your words and actions in order for the change to occur. You also need to play an integral role in developing the implementing policies and procedures for your programs.

I am issuing the attached EPA Risk Characterization Policy and Guidance today. I view these documents as building blocks for the development of your program-specific policies and procedures. The Science Policy Council (SPC) plans to adopt the same basic approach to implementation as was used for Peer Review. That is, the Council will form an Advisory Group that will work with a broad Implementation Team made up of representatives from every Program Office and Region. Each Program Office and each Region will be asked by the Advisory Group to develop program and region-specific policies and procedures for risk characterization consistent with the values of **transparency, clarity, consistency, and reasonableness** and consistent with the attached policy and guidance.

I recognize that as you develop your Program-specific policies and procedures you are likely to need additional tools to fully implement this policy. I want you to identify these needed tools and work cooperatively with the Science Policy Council in their development. I want your draft program and region-specific policies, procedures, and implementation plans to be developed and submitted to the Advisory Group for review by no later than May 30, 1995. You will be contacted shortly by the SPC Steering Committee to obtain the names of your nominees to the Implementation Team.

Carol M. Browner

Carol M. Browner

Attachments

March 1995

POLICY FOR RISK CHARACTERIZATION
at the U.S. Environmental Protection Agency

INTRODUCTION

Many EPA policy decisions are based in part on the results of risk assessment, an analysis of scientific information on existing and projected risks to human health and the environment. As practiced at EPA, risk assessment makes use of many different kinds of scientific concepts and data (e.g., exposure, toxicity, epidemiology, ecology), all of which are used to "characterize" the expected risk associated with a particular agent or action in a particular environmental context. Informed use of reliable scientific information from many different sources is a central feature of the risk assessment process.

Reliable information may or may not be available for many aspects of a risk assessment. Scientific uncertainty is a fact of life for the risk assessment process, and agency managers almost always must make decisions using assessments that are not as definitive in all important areas as would be desirable. They therefore need to understand the strengths and the limitations of each assessment, and to communicate this information to all participants and the public.

This policy reaffirms the principles and guidance found in the Agency's 1992 policy (Guidance on Risk Characterization for Risk Managers and Risk Assessors, February 26, 1992). That guidance was based on EPA's risk assessment guidelines, which are products of peer review and public comment. The 1994 National Research Council (NRC) report, "Science and Judgment in Risk Assessment," addressed the Agency's approach to risk assessment, including the 1992 risk characterization policy. The NRC statement accompanying the report stated, "... EPA's overall approach to assessing risks is fundamentally sound despite often-heard criticisms, but the Agency must more clearly establish the scientific and policy basis for risk estimates and better describe the uncertainties in its estimates of risk."

This policy statement and associated guidance for risk characterization is designed to ensure that critical information from each stage of a risk assessment is used in forming conclusions about risk and that this information is communicated from risk assessors to risk managers (policy makers), from middle to upper management, and from the Agency to the public. Additionally, the policy will provide a basis for greater clarity, transparency, reasonableness, and consistency in risk assessments across Agency programs. While most of the discussion and examples in this policy are drawn from health risk assessment, these values also apply to ecological risk assessment. A parallel effort by the Risk Assessment Forum to develop EPA ecological risk assessment guidelines will include guidance specific to ecological risk characterization.

Policy Statement

Each risk assessment prepared in support of decision-making at EPA should include a risk characterization that follows the principles and reflects the values outlined in this policy. A risk characterization should be prepared in a manner that is clear, transparent, reasonable and consistent with other risk characterizations of similar scope prepared across programs in the Agency. Further, discussion of risk in all EPA reports, presentations, decision packages, and other documents should be substantively consistent with the risk characterization. The nature of the risk characterization will depend upon the information available, the regulatory application of the risk information, and the resources (including time) available. In all cases, however, the assessment should identify and discuss all the major issues associated with determining the nature and extent of the risk and provide commentary on any constraints limiting fuller exposition.

Key Aspects of Risk Characterization

Bridging risk assessment and risk management. As the interface between risk assessment and risk management, risk characterizations should be clearly presented, and separate from any risk management considerations. Risk management options should be developed using the risk characterization and should be based on consideration of all relevant factors, scientific and nonscientific.

Discussing confidence and uncertainties. Key scientific concepts, data and methods (e.g., use of animal or human data for extrapolating from high to low doses, use of pharmacokinetics data, exposure pathways, sampling methods, availability of chemical-specific information, quality of data) should be discussed. To ensure transparency, risk characterizations should include a statement of confidence in the assessment that identifies all major uncertainties along with comment on their influence on the assessment, consistent with the Guidance on Risk Characterization (attached).

Presenting several types of risk information. Information should be presented on the range of exposures derived from exposure scenarios and on the use of multiple risk descriptors (e.g., central tendency, high end of individual risk, population risk, important subgroups, if known) consistent with terminology in the Guidance on Risk Characterization, Agency risk assessment guidelines, and program-specific guidance. In decision-making, risk managers should use risk information appropriate to their program legislation.

EPA conducts many types of risk assessments, including screening-level assessments of new chemicals, in-depth assessments of pollutants such as dioxin and environmental tobacco smoke, and site-specific assessments for hazardous waste sites. An iterative approach to risk assessment, beginning with screening techniques, may be used to determine if a more comprehensive assessment is necessary. The degree to which confidence and uncertainty are addressed in a risk characterization depends largely on the scope of the assessment. In general, the scope of the risk characterization should reflect the information presented in the risk assessment and program-specific guidance. When special circumstances (e.g., lack of data, extremely complex situations, resource limitations, statutory deadlines) preclude a full assessment, such circumstances should be explained and their impact on the risk assessment discussed.

Risk Characterization in Context

Risk assessment is based on a series of questions that the assessor asks about scientific information that is relevant to human and/or environmental risk. Each question calls for analysis and interpretation of the available studies, selection of the concepts and data that are most scientifically reliable and most relevant to the problem at hand, and scientific conclusions regarding the question presented. For example, health risk assessments involve the following questions:

Hazard Identification -- What is known about the capacity of an environmental agent for causing cancer or other adverse health effects in humans, laboratory animals, or wildlife species? What are the related uncertainties and science policy choices?

Dose-Response Assessment -- What is known about the biological mechanisms and dose-response relationships underlying any effects observed in the laboratory or epidemiology studies providing data for the assessment? What are the related uncertainties and science policy choices?

Exposure Assessment -- What is known about the principal paths, patterns, and magnitudes of human or wildlife exposure and numbers of persons or wildlife species likely to be exposed? What are the related uncertainties and science policy choices?

Corresponding principles and questions for ecological risk assessment are being discussed as part of the effort to develop ecological risk guidelines.

Risk characterization is the summarizing step of risk assessment. The risk characterization integrates information from the preceding components of the risk assessment and synthesizes an overall conclusion about risk that is complete, informative and useful for decisionmakers.

Risk characterizations should clearly highlight both the confidence and the uncertainty associated with the risk assessment. For example, numerical risk estimates should always be accompanied by descriptive information carefully selected to ensure an objective and balanced characterization of risk in risk assessment reports and regulatory documents. In essence, a risk characterization conveys the assessor's judgment as to the nature and existence of (or lack of) human health or ecological risks. Even though a risk characterization describes limitations in an assessment, a balanced discussion of reasonable conclusions and related uncertainties enhances, rather than detracts, from the overall credibility of each assessment.

"Risk characterization" is not synonymous with "risk communication." This risk characterization policy addresses the interface between risk assessment and risk management. Risk communication, in contrast, emphasizes the process of exchanging information and opinion with the public -- including individuals, groups, and other institutions. The development of a risk assessment may involve risk communication. For example, in the case of site-specific assessments for hazardous waste sites, discussions with the public may influence the exposure pathways included in the risk assessment. While the final risk assessment document (including the risk characterization) is available to the public, the risk communication process may be better served by separate risk information documents designed for particular audiences.

Promoting Clarity, Comparability and Consistency

There are several reasons that the Agency should strive for greater clarity, consistency and comparability in risk assessments. One reason is to minimize confusion. For example, many people have not understood that a risk estimate of one in a million for an "average" individual is not comparable to another one in a million risk estimate for the "most exposed individual." Use of such apparently similar estimates without further explanation leads to misunderstandings about the relative significance of risks and the protectiveness of risk reduction actions.

EPA's Exposure Assessment Guidelines provide standard descriptors of exposure and risk. Use of these terms in all Agency risk assessments will promote consistency and comparability. Use of several descriptors, rather than a single descriptor, will enable EPA to present a fuller picture of risk that corresponds to the range of different exposure conditions encountered by various individuals and populations exposed to most environmental chemicals.

Legal Effect

This policy statement and associated guidance on risk characterization do not establish or affect legal rights or obligations. Rather, they confirm the importance of risk characterization as a component of risk assessment, outline relevant principles, and identify factors Agency staff should consider in implementing the policy.

The policy and associated guidance do not stand alone; nor do they establish a binding norm that is finally determinative of the issues addressed. Except where otherwise provided by law, the Agency's decision on conducting a risk assessment in any particular case is within the Agency's discretion. Variations in the application of the policy and associated guidance, therefore, are not a legitimate basis for delaying or complicating action on Agency decisions.

Applicability

Except where otherwise provided by law and subject to the limitations on the policy's legal effect discussed above, this policy applies to risk assessments prepared by EPA and to risk assessments prepared by others that are used in support of EPA decisions.

EPA will consider the principles in this policy in evaluating assessments submitted to EPA to complement or challenge Agency assessments. Adherence to this Agency-wide policy will improve understanding of Agency risk assessments, lead to more informed decisions, and heighten the credibility of both assessments and decisions.

Implementation

Assistant Administrators and Regional Administrators are responsible for implementation of this policy within their organizational units. The Science Policy Council (SPC) is organizing Agency-wide implementation activities. Its responsibilities include promoting consistent interpretation, assessing Agency-wide progress, working with external groups on risk characterization issues and methods, and developing recommendations for revisions of the policy and guidance, as necessary.

Each Program and Regional office will develop office-specific policies and procedures for risk characterization that are consistent with this policy and the associated guidance. Each Program and Regional office will designate a risk manager or risk assessor as the office representative to the Agency-wide Implementation Team, which will coordinate development of office-specific policies and procedures and other implementation activities. The SPC will also designate a small cross-Agency Advisory Group that will serve as the liaison between the SPC and the Implementation Team.

In ensuring coordination and consistency among EPA offices, the Implementation Team will take into account statutory and court deadlines, resource implications, and existing Agency and program-specific guidance on risk assessment. The group will work closely with staff throughout Headquarters and Regional offices to promote development of risk characterizations that present a full and complete picture of risk that meets the needs of the risk managers.

APPROVED: Carol M. Browner DATE: MAR 2 1 1995

Carol M. Browner, Administrator

ELEMENTS TO CONSIDER WHEN DRAFTING EPA RISK CHARACTERIZATIONS
March 1995

Background -- Risk Characterization Principles

There are a number of principles which form the basis for a risk characterization:

- Risk assessments should be transparent, in that the conclusions drawn from the science are identified separately from policy judgements, and the use of default values or methods and the use of assumptions in the risk assessment are clearly articulated.
- Risk characterizations should include a summary of the key issues and conclusions of each of the other components of the risk assessment, as well as describe the likelihood of harm. The summary should include a description of the overall strengths and the limitations (including uncertainties) of the assessment and conclusions.
- Risk characterizations should be consistent in general format, but recognize the unique characteristics of each specific situation.
- Risk characterizations should include, at least in a qualitative sense, a discussion of how a specific risk and its context compares with other similar risks. This may be accomplished by comparisons with other chemicals or situations in which the Agency has decided to act, or with other situations which the public may be familiar with. The discussion should highlight the limitations of such comparisons.
- Risk characterization is a key component of risk communication, which is an interactive process involving exchange of information and export opinion among individuals, groups and institutions.

Conceptual Guide for Developing Chemical-Specific Risk Characterizations

The following outline is a guide and formatting aid for developing risk characterizations for chemical risk assessments. Similar outlines will be developed for other types of risk characterizations, including site-specific assessments and ecological risk assessments. A common format will assist risk managers in evaluating and using risk characterization.

The outline has two parts. The first part tracks the risk assessment to bring forward its major conclusions. The second part draws all of the information together to characterize risk. The outline represents the expected findings for a typical complete chemical assessment for a single chemical. However, exceptions for the circumstances of individual assessments exist and should be explained as part of the risk characterization. For example, particular statutory requirements, court-ordered deadlines, resource limitations, and other specific factors may be described to explain why certain elements are incomplete.

This outline does not establish or affect legal rights or obligations. Rather, it confirms the importance of risk characterization, outlines relevant principles, and identifies factors Agency staff should consider in implementing the policy. On a continuing basis, Agency management is expected to evaluate the policy as well as the results of its application throughout the Agency and undertake revisions as necessary. Therefore, the policy does not stand alone; nor does it establish a binding norm that is finally determinative of the issues addressed. Minor variations in its application from one instance to another are appropriate and expected; they thus are not a legitimate basis for delaying or complicating action on otherwise satisfactory scientific, technical, and regulatory products.

PART ONE

SUMMARIZING MAJOR CONCLUSIONS IN RISK CHARACTERIZATION

I. Characterization of Hazard Identification

A. What is the key toxicological study (or studies) that provides the basis for health concerns?
   - How good is the key study?
   - Are the data from laboratory or field studies? In single species or multiple species?
   - If the hazard is carcinogenic, comment on issues such as: observation of single or multiple tumor sites; occurrence of benign or malignant tumors; certain tumor types not linked to carcinogenicity; use of the maximum tolerated dose (MTD).
   - If the hazard is other than carcinogenic, what endpoints were observed, and what is the basis for the critical effect?
   - Describe other studies that support this finding.
   - Discuss any valid studies which conflict with this finding.

B. Besides the health effect observed in the key study, are there other health endpoints of concern?
   - What are the significant data gaps?

C. Discuss available epidemiological or clinical data. For epidemiological studies:
   - What types of studies were used, i.e., ecologic, case-control, cohort?

- Describe the degree to which exposures were adequately described.
- Describe the degree to which confounding factors were adequately accounted for.
- Describe the degree to which other causal factors were excluded.

D. How much is known about how (through what biological mechanism) the chemical produces adverse effects?
   - Discuss relevant studies of mechanisms of action or metabolism.
   - Does this information aid in the interpretation of the toxicity data?
   - What are the implications for potential health effects?

E. Comment on any non-positive data in animals or people, and whether these data were considered in the hazard identification.

F. If adverse health affects have been observed in wildlife species, characterize such effects by discussing the relevant issues as in A through E above.

G. Summarize the hazard identification and discuss the significance of each of he following:
   - confidence in conclusions;
   - alternative conclusions that are also supported by the data;
   - significant data gaps; and
   - highlights of major assumptions.

II. Characterization of Dose-Response

A. What data were used to develop the dose-response curve? Would the result have been significantly different if based on a different data set?
   - If animal data were used:
     - which species were used? most sensitive, average of all species, or other?
     - were any studies excluded? why?
   - If epidemiological data were used:
     - Which studies were used? only positive studies, all studies, or some other combination?
     - Were any studies excluded? why?
     - Was a meta-analysis performed to combine the epidemiological studies? what approach was used? were studies excluded? why?

B. What model was used to develop the dose-response curve? What rationale supports this choice? Is chemical-specific information available to support this approach?
   - For non-carcinogenic hazards:
     - How was the RfD/RfC (or the acceptable range) calculated?

- What assumptions or uncertainty factors were used?
- What is the confidence in the estimates?
- For carcinogenic hazards:
  - What dose-response model was used? LMS or other linear-at-low-dose model, a biologically-based model based on metabolism data, or data about possible mechanisms of action?
  - What is the basis for the selection of the particular dose-response model used? Are there other models that could have been used with equal plausibility and scientific validity? What is the basis for selection of the model used in this instance?

C. Discuss the route and level of exposure observed, as compared to expected human exposures.
- Are the available data from the same route of exposure as the expected human exposures? If not, are pharmacokinetic data available to extrapolate across route of exposure?
- How far does one need to extrapolate from the observed data to environmental exposures (one to two orders of magnitude? multiple orders of magnitude)? What is the impact of such an extrapolation?

D. If adverse health affects have been observed in wildlife species, characterize dose-response information using the process outlined in A-C.

III. Characterization of Exposure

A. What are the most significant sources of environmental exposure?
- Are there data on sources of exposure from different media? What is the relative contribution of different sources of exposure?
- What are the most significant environmental pathways for exposure?

B. Describe the populations that were assessed, including as the general population, highly exposed groups, and highly susceptible groups.

C. Describe the basis for the exposure assessment, including any monitoring, modeling, or other analyses of exposure distributions such as Monte-Carlo or krieging.

D. What are the key descriptors of exposure?
- Describe the (range of) exposures to: "average" individuals, "high end" individuals, general population, high exposure group(s), children, susceptible populations.
- How was the central tendency estimate developed? What factors and/or methods were used in developing this estimate?
- How was the high-end estimate developed?

- Is there information on highly-exposed subgroups? Who are they? What are their levels of exposure? How are they accounted for in the assessment?

E. Is there reason to be concerned about cumulative or multiple exposures because of ethnic, racial, or socioeconomic reasons?

F. If adverse health affects have been observed in wildlife species, characterize wildlife exposure by discussing the relevant issues as in A through E above.

G. Summarize exposure conclusions and discuss the following:
- results of different approaches, i.e. modeling, monitoring, probability distributions;
- limitations of each, and the range of most reasonable values; and
- confidence in the results obtained, and the limitations to the results.

PART TWO
RISK CONCLUSIONS AND COMPARISONS

IV. Risk Conclusions

A. What is the overall picture of risk, based on the hazard identification, dose-response and exposure characterizations?

B. What are the major conclusions and strengths of the assessment in each of the three main analyses (i.e., hazard identification, dose-response, and exposure assessment)?

C. What are the major limitations and uncertainties in the three main analyses?

D. What are the science policy options in each of the three major analyses?
- What are the alternative approaches evaluated?
- What are the reasons for the choices made?

V. Risk Context

A. What are the qualitative characteristics of the hazard (e.g., voluntary vs. involuntary, technological vs. natural, etc.)? Comment on findings, if any, from studies of risk perception that relate to this hazard or similar hazards.

B. What are the alternatives to this hazard? How do the risks compare?

C. How does this risk compare to other risks?
   1. How does this risk compare to other risks in this regulatory program, or other similar risks that the EPA has made decisions about?
   2. Where appropriate, can this risk be compared with past Agency decisions, decisions by other federal or state agencies, or common risks with which people may be familiar?
   3. Describe the limitations of making these comparisons.

D. Comment on significant community concerns which influence public perception of risk?

VI. Existing Risk Information

Comment on other risk assessments that have been done on this chemical by EPA, other federal agencies, or other organizations. Are there significantly different conclusions that merit discussion?

VII. Other Information

Is there other information that would be useful to the risk manager or the public in this situation that has not been described above?

March 1995

IMPLEMENTATION PROGRAM
FOR
THE EPA POLICY ON RISK CHARACTERIZATION

Introduction

The EPA Science Policy Council (SPC) is implementing the Administrator's policy on risk characterization through a year-long program of activities that will involve risk assessors and risk managers in the practice of fully characterizing risk. This interactive approach calls for inter- and intra-office activities to gain experience with the fundamentals of the policy and to resolve issues that were identified during Agency-wide review of early drafts. Implementation will include program-specific guidance development; case study development; and risk characterization workshops and rountables for risk assessors and managers.

A SPC-sponsored "advisory group" will plan and execute these implementation activities. This advisory group will organize an "implementation team" composed of representatives from the program offices, regions and ORD laboratories and centers. This team will work closely with the advisory group to coordinate implementation activities within their offices.

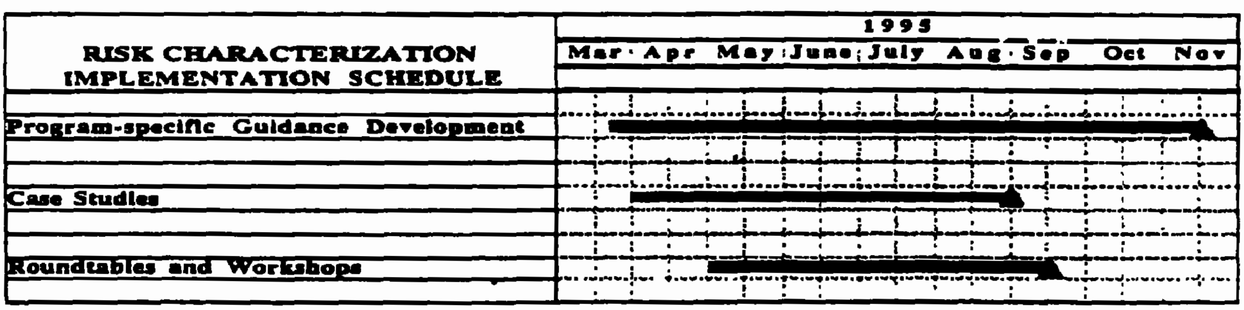
Program Guidance Development

Risk characterizations often differ according to the type of assessment involved. The aim is to work closely with the Program Offices and Regions to identify and address their specific risk characterization needs and, where appropriate, to develop assessment-specific guidance.

This program updates and implements the risk characterization guidance issued in early 1992. The policy features a paper entitled "Elements to Consider When Drafting EPA Risk Characterizations." This paper outlines generic elements for characterizing risk, and provides a prototype for assessment-specific guidance. Program and Regional offices will use this paper to identify and address risk characterization issues associated with specific assessment types that differ from the general prototype (e.g., site-specific and ecological risk assessments). Lessons learned from the case studies, roundtables and workshops (discussed below) will also contribute to program-specific guidance development.

Case Studies

Today, when asked to provide an example of a "good" risk characterization, few people can identify good examples, let alone examples that others would agree are



of high quality. As a first step, a selected number of risk characterization case studies will be developed for use as teaching tools. A "case study" will be an exercise to improve an existing risk characterization, using the information available in an existing risk assessment. While based on actual risk assessments, identifying information (e.g., site identification information) will be removed to avoid any implied judgement as to the adequacy of the original risk assessment and risk characterization. Examples of case studies may include a chemical assessment, a site-specific assessment, and a screening-level assessment. The case studies will be developed by the risk characterization advisory group, working in consultation with the implementation team, and will be used for discussion at the first risk characterization workshop.

Roundtables and Workshops

EPA decision-makers will be invited to participate in roundtable discussions on risk characterization. In addition, a minimum of two workshops are planned for EPA risk assessors and risk managers.

° ***Risk Decision-maker Rountables on Risk Characterization*** - The goal will be to determine the types of risk characterization information needed by managers for effective risk-based decision-making.

° ***Risk Characterization Workshop I*** - Will focus on identifying the qualities of "good" risk characterizations, program-specific plans and guidance development, and case studies.

° ***Risk Characterization Workshop II*** - Risk assessors and risk managers will meet to wrap-up program-specific plans and guidance, and discuss any necessary updates to the agency-wide risk characterization guidance.

GUIDANCE FOR RISK CHARACTERIZATION

U.S. Environmental Protection Agency
Science Policy Council
February, 1995

CONTENTS

PREFACE

This guidance contains principles for developing and describing EPA risk assessments, with a particular emphasis on risk characterization. The current document is an update of the guidance issued with the Agency's 1992 policy (Guidance on Risk Characterization for Risk Managers and Risk Assessors, February 26, 1992). The guidance has not been substantially revised, but includes some clarifications and changes to give more prominence to certain issues, such as the need to explain the use of default assumptions.

As in the 1992 policy, some aspects of this guidance focus on cancer risk assessment, but the guidance applies generally to human health effects (e.g., neurotoxicity, developmental toxicity) and, with appropriate modifications, should be used in all health risk assessments. This document has not been revised to specifically address ecological risk assessment, however, initial guidance for ecological risk characterization is included in EPA's Framework for Ecological Risk Assessments (EPA/630/R-92/001). Neither does this guidance address in detail the use of risk assessment information (e.g., information from the Integrated Risk Information System (IRIS)) to generate site- or media-specific risk assessments. Additional program-specific guidance will be developed to enable implementation of EPA's Risk Characterization Policy. Development of such guidance will be overseen by the Science Policy Council and will involve risk assessors and risk managers from across the Agency.

I. THE RISK ASSESSMENT-RISK MANAGEMENT INTERFACE

Recognizing that for many people the term risk assessment has wide meaning, the National Research Council's 1983 report on risk assessment in the federal government distinguished between risk assessment and risk management.

> "Broader uses of the term [risk assessment] than ours also embrace analysis of perceived risks, comparisons of risks associated with different regulatory strategies, and occasionally analysis of the economic and social implications of regulatory decisions -- <u>functions that we assign to risk management</u> (emphasis added). (1)

In 1984, EPA endorsed these distinctions between risk assessment and risk management for Agency use (2), and later relied on them in developing risk assessment guidelines (3). In 1994, the NRC reviewed the Agency's approach to and use of risk assessment and issued an extensive report on their findings (4). This distinction suggests that EPA participants in the process can be grouped into two main categories, each with somewhat different responsibilities, based on their roles with respect to risk assessment and risk management.

A. Roles of Risk Assessors and Risk Managers

Within the Risk Assessment category there is a group that develops chemical-specific risk assessments by collecting, analyzing, and synthesizing scientific data to produce the hazard identification, dose-response, and exposure assessment portion of the risk assessment and to characterize risk. This group relies in part on Agency risk assessment guidelines to address science policy issues and scientific uncertainties. Generally, this group includes scientists and statisticians in the Office of Research and Development; the Office of Prevention, Pesticides and Toxics and other program offices; the Carcinogen Risk Assessment Verification Endeavor (CRAVE); and the Reference Dose (RfD) and Reference Concentration (RfC) Workgroups.

Another group generates site- or media-specific risk assessments for use in regulation development or site-specific decision-making. These assessors rely on existing databases (e.g., IRIS, ORD Health Assessment Documents, CRAVE and RfD/RfC Workgroup documents, and program-specific toxicity information) and media- or site-specific exposure information in developing risk assessments. This group also relies in part on Agency risk assessment guidelines and program-specific guidance to address science policy issues and scientific uncertainties. Generally, this group includes scientists and analysts in program offices, regional offices, and the Office of Research and Development.

Risk managers, as a separate category, integrate the risk characterization with other considerations specified in applicable statutes to make and justify regulatory decisions. Generally, this group includes Agency managers and decision-makers. Risk managers also play a role in determining the scope of risk assessments. The risk assessment process involves regular interaction between risk assessors and risk managers, with overlapping responsibilities at various stages in the overall process. Shared responsibilities include initial decisions regarding the planning and conduct of an assessment, discussions as the assessment develops, decisions regarding new data needed to complete an assessment and to address significant uncertainties. At critical junctures in the assessment, such consultations shape the nature of, and schedule for, the assessment. External experts and members of the public may also play a role in determining the scope of the assessment; for example, the public is often concerned about certain chemicals or exposure pathways in the development of site-specific risk assessments.

B. Guiding Principles

The following guidance outlines principles for those who generate, review, use, and integrate risk assessments for decision-making.

1. **Risk assessors and risk managers should be sensitive to distinctions between risk assessment and risk management.**

The major participants in the risk assessment process have many shared responsibilities. Where responsibilities differ, it is important that participants confine themselves to tasks in their areas of responsibility and not inadvertently obscure differences between risk assessment and risk management.

For the generators of the assessment, distinguishing between risk assessment and risk management means that scientific information is selected, evaluated, and presented without considering issues such as cost, feasibility, or how the scientific analysis might influence the regulatory or site-specific decision. Assessors are charged with (1) generating a credible, objective, realistic, and scientifically balanced analysis; (2) presenting information on hazard, dose-response, exposure and risk; and (3) explaining confidence in each assessment by clearly delineating strengths, uncertainties and assumptions, along with the impacts of these factors (e.g., confidence limits, use of conservative/non-conservative assumptions) on the overall assessment. They do not make decisions on the acceptability of any risk level for protecting public health or selecting procedures for reducing risks.

For users of the assessment and for decision-makers who integrate these assessments into regulatory or site-specific decisions, the distinction between risk assessment and risk management means refraining from influencing the risk description through consideration of other factors -- e.g., the regulatory outcome -- and from attempting to shape the risk assessment to avoid statutory constraints, meet regulatory objectives, or serve political purposes. Such management considerations are often legitimate considerations for the overall regulatory decision (see next principle), but they have no role in estimating or describing risk. However, decision-makers and risk assessors participate in an Agency process that establishes policy directions that determine the overall nature and tone of Agency risk assessments and, as appropriate, provide policy guidance on difficult and controversial risk assessment issues. Matters such as risk assessment priorities, degree of conservatism, and acceptability of particular risk levels are reserved for decision-makers who are charged with making decisions regarding protection of public health.

2. **The risk assessment product, that is, the risk characterization, is only one of several kinds of information used for regulatory decision-making.**

Risk characterization, the last step in risk assessment, is the starting point for risk management considerations and the foundation for regulatory decision-making, but it is only one of several important components in such decisions. As the last step in risk assessment, the risk characterization identifies and highlights the noteworthy risk conclusions and related uncertainties. Each of the environmental laws administered by EPA calls for consideration of other factors at various stages in the regulatory process. As authorized by different statutes, decision-makers evaluate technical feasibility (e.g., treatability, detection limits), economic, social, political, and legal factors as part of the analysis of whether or not to regulate and, if so, to what extent. Thus, regulatory decisions are usually based on a combination of the technical analysis used to develop the risk assessment and information from other fields.

For this reason, risk assessors and managers should understand that the regulatory decision is usually not determined solely by the outcome of the risk assessment. For example, a regulatory decision on the use of a particular pesticide considers not only the risk level to affected populations, but also the agricultural benefits of its use that may be important for the nation's food supply. Similarly, assessment efforts may produce an RfD for a particular chemical, but other considerations may result in a regulatory level that is more or less protective than the RfD itself.

For decision-makers, this means that societal considerations (e.g., costs and benefits) that, along with the risk assessment, shape the regulatory decision should be described as fully as the scientific information set forth in the risk characterization. Information on data sources and analyses, their strengths and limitations, confidence in the assessment, uncertainties, and alternative analyses are as important here as they are for the scientific components of the regulatory decision. Decision-makers should be able to expect, for example, the same level of rigor from the economic analysis as they receive from the risk analysis. Risk management decisions involve numerous assumptions and uncertainties regarding technology, economics and social factors, which need to be explicitly identified for the decision-makers and the public.

II. RISK CHARACTERIZATION

A. Defining Risk Characterization in the Context of Risk Assessment

EPA risk assessment principles and practices draw on many sources. Obvious sources include the environmental laws administered by EPA, the National Research Council's 1983 report on risk assessment (1), the Agency's Risk Assessment Guidelines (3), and various program specific guidance (e.g., the Risk Assessment Guidance for Superfund). Twenty years of EPA experience in developing, defending, and enforcing risk assessment-based regulation is another. Together these various sources stress the importance of a clear explanation of Agency processes for evaluating hazard, dose-response, exposure, and other data that provide the scientific foundation for characterizing risk.

This section focuses on two requirements for full characterization of risk. First, the characterization should address qualitative and quantitative features of the assessment. Second, it should identify the important strengths and uncertainties in the assessment as part of a discussion of the confidence in the assessment. This emphasis on a full description of all elements of the assessment draws attention to the importance of the qualitative, as well as the quantitative, dimensions of the assessment. The 1983 NRC report carefully distinguished qualitative risk assessment from quantitative assessments, preferring risk statements that are not strictly numerical.

> The term risk assessment is often given narrower and broader meanings than we have adopted here. For some observers, the term is synonymous with quantitative risk assessment and emphasizes reliance on numerical results. Our broader definition includes quantification, but also includes qualitative expressions of risk. Quantitative estimates of risk are not always feasible, and they may be eschewed by agencies for policy reasons. (1)

EPA's Exposure Assessment Guidelines define risk characterization as the final step in the risk assessment process that:

- Integrates the individual characterizations from the hazard identification, dose-response, and exposure assessments;

- Provides an evaluation of the overall quality of the assessment and the degree of confidence the authors have in the estimates of risk and conclusions drawn;

- Describes risks to individuals and populations in terms of extent and severity of probable harm; and

- Communicates results of the risk assessment to the risk manager. (5)

Particularly critical to full characterization of risk is a frank and open discussion of the uncertainty in the overall assessment and in each of its components. The uncertainty discussion is important for several reasons.

1. Information from different sources carries different kinds of uncertainty and knowledge of these differences is important when uncertainties are combined for characterizing risk.

2. The risk assessment process, with management input, involves decisions regarding the collection of additional data (versus living with uncertainty); in the risk characterization, a discussion of the uncertainties will help to identify where additional information could contribute significantly to reducing uncertainties in risk assessment.

3. A clear and explicit statement of the strengths and limitations of a risk assessment requires a clear and explicit statement of related uncertainties.

A discussion of uncertainty requires comment on such issues as the quality and quantity of available data, gaps in the data base for specific chemicals, quality of the measured data, use of default assumptions, incomplete understanding of general biological phenomena, and scientific judgments or science policy positions that were employed to bridge information gaps.

In short, broad agreement exists on the importance of a full picture of risk, particularly including a statement of confidence in the assessment and the associated uncertainties. This section discusses information content and uncertainty aspects of risk characterization, while Section III discusses various descriptors used in risk characterization.

B. Guiding Principles

1. **The risk characterization integrates the information from the hazard identification, dose-response, and exposure assessments, using a combination of qualitative information, quantitative information, and information regarding uncertainties.**

Risk assessment is based on a series of questions that the assessor asks about the data and the implications of the data for human risk. Each question calls for analysis and interpretation of the available studies, selection of the data that are most scientifically reliable and most relevant to the problem at hand, and scientific conclusions regarding the question presented. As suggested below, because the questions and analyses are complex, a complete characterization includes several different kinds of information, carefully selected for reliability and relevance.

a. *Hazard Identification* -- What is known about the capacity of an environmental agent for causing cancer (or other adverse effects) in humans and laboratory animals?

Hazard identification is a qualitative description based on factors such as the kind and quality of data on humans or laboratory animals, the availability of ancillary information (e.g., structure-activity analysis, genetic toxicity, pharmacokinetics) from other studies, and the weight-of-the-evidence from all of these data sources. For example, to develop this description, the issues addressed include:

1) the nature, reliability, and consistency of the particular studies in humans and in laboratory animals;

2) the available information on the mechanistic basis for activity; and

3) experimental animal responses and their relevance to human outcomes.

These issues make clear that the task of hazard identification is characterized by describing the full range of available information and the implications of that information for human health.

b. *Dose-Response Assessment* -- What is known about the biological mechanisms and dose-response relationships underlying any effects observed in the laboratory or epidemiology studies providing data for the assessment?

The dose-response assessment examines quantitative relationships between exposure (or dose) and effects in the studies used to identify and define effects of concern. This information is later used along with "real world" exposure information (see below) to develop estimates of the likelihood of adverse effects in populations potentially at risk. It should be noted that, in practice, hazard identification for developmental toxicity and other non-cancer health effects is usually done in conjunction with an evaluation of dose-response relationships, since the determination of whether there is a hazard is often dependent on whether a dose response relationship is present. (6) Also, the framework developed by EPA for ecological risk assessment does not distinguish between hazard identification and dose-response assessment, but rather calls for a "characterization of ecological effects." (7)

Methods for establishing dose-response relationships often depend on various assumptions used in lieu of a complete data base, and the method chosen can strongly influence the overall assessment. The Agency's risk assessment guidelines often identify so-called "default assumptions" for use in the absence of other information. The risk assessment should pay careful attention to the choice of a high-to-low dose extrapolation procedure. As a result, an assessor who is characterizing a dose-response relationship considers several key issues:

1) the relationship between extrapolation models selected and available information on biological mechanisms;

2) how appropriate data sets were selected from those that show the range of possible potencies both in laboratory animals and humans;

3) the basis for selecting interspecies dose scaling factors to account for scaling doses from experimental animals to humans;

4) the correspondence between the expected route(s) of exposure and the exposure route(s) utilized in the studies forming the basis of the dose-response assessment, as well as the interrelationships of potential effects from different exposure routes;

5) the correspondence between the expected duration of exposure and the exposure durations in the studies used in forming the basis of the dose-response assessment, e.g., chronic studies would be used to assess long-term, cumulative exposure concentrations, while acute studies would be used in assessing peak levels of exposure; and

6) the potential for differing susceptibilities among population subgroups.

The Agency's Integrated Risk Information System (IRIS) is a repository for such information for EPA. EPA program offices also maintain program-specific databases, such as the OSWER Health Effects Assessment Summary Tables (HEAST). IRIS includes data summaries representing Agency consensus on specific chemicals, based on a careful review of the scientific issues listed above. For specific risk assessments based on data from any source, risk assessors should carefully review the information presented, emphasizing confidence in the data and uncertainties (see subsection 2 below). Specifically, when IRIS data are used, the IRIS statement of confidence should be included as an explicit part of the risk characterization for hazard and dose-response information.

c. *Exposure Assessment* – What is known about the principal paths, patterns, and magnitudes of human exposure and numbers of persons who may be exposed?

The exposure assessment examines a wide range of exposure parameters pertaining to the environmental scenarios of people who may be exposed to the agent under study. The information considered for the exposure assessment includes monitoring studies of chemical concentrations in environmental media, food, and other materials; modeling of environmental fate and transport of contaminants; and information on different activity patterns of different population subgroups. An assessor who characterizes exposure should address several issues:

1) The basis for the values and input parameters used for each exposure scenario. If the values are based on data, there should be a discussion of the quality, purpose, and representativeness of the database. For monitoring data, there should be a discussion of the data quality objectives as they are relevant to risk

assessment, including the appropriateness of the analytical detection limits. If models are applied, the appropriateness of the models and information on their validation should be presented. When assumptions are made, the source and general logic used to develop the assumptions (e.g., program guidance, analogy, professional judgment) should be described.

2) The confidence in the assumptions made about human behavior and the relative likelihood of the different exposure scenarios.

3) The major factor or factors (e.g., concentration, body uptake, duration/frequency of exposure) thought to account for the greatest uncertainty in the exposure estimate, due either to sensitivity or lack of data.

4) The link between the exposure information and the risk descriptors discussed in Section III of this Appendix. Specifically, the risk assessor needs to discuss the connection between the conservatism or non-conservatism of the data/assumptions used in the scenarios and the choice of descriptors.

5) Other information that may be important for the particular risk assessment. For example, for many assessments, other sources and background levels in the environment may contribute significantly to population exposures and should be discussed.

2) The risk characterization includes a discussion of uncertainty and variability.

In the risk characterization, conclusions about hazard and dose response are integrated with those from the exposure assessment. In addition, confidence about these conclusions, including information about the uncertainties associated with each aspect of the assessment in the final risk summary, is highlighted. In the previous assessment steps and in the risk characterization, the risk assessor must distinguish between <u>variability</u> and <u>uncertainty</u>.

Variability arises from true heterogeneity in characteristics such as dose-response differences within a population, or differences in contaminant levels in the environment. The values of some variables used in an assessment change with time and space, or across the population whose exposure is being estimated. Assessments should address the resulting variability in doses received by members of the target population. Individual exposure, dose, and risk can vary widely in a large population. The central tendency and high end individual risk descriptors (discussed in Section III below) are intended to capture the <u>variability</u> in exposure, lifestyles, and other factors that lead to a distribution of risk across a population.

Uncertainty, on the other hand, represents lack of knowledge about factors such as adverse effects or contaminant levels which may be reduced with additional study. Generally, risk assessments carry several categories of uncertainty, and each merits consideration. Measurement uncertainty refers to the usual error that accompanies scientific measurements--standard statistical techniques can often be used to express measurement uncertainty. A substantial amount of uncertainty is often inherent in environmental sampling, and assessments should address these uncertainties. There are likewise uncertainties associated with the use of scientific models, e.g., dose-response models,.models of environmental fate and transport. Evaluation of model uncertainty would consider the scientific basis for the model and available empirical validation.

A different kind of uncertainty stems from data gaps -- that is, estimates or assumptions used in the assessment. Often, the data gap is broad, such as the absence of information on the effects of exposure to a chemical on humans or on the biological mechanism of action of an agent. The risk assessor should include a statement of confidence that reflects the degree to which the risk assessor believes that the estimates or assumptions adequately fill the data gap. For some common and important data gaps, Agency or program-specific risk assessment guidance provides default assumptions or values. Risk assessors should carefully consider all available data before deciding to rely on default assumptions. If defaults are used, the risk assessment should reference the Agency guidance that explains the default assumptions or values.

Often risk assessors and managers simplify discussion of risk issues by speaking only of the numerical components of an assessment. That is, they refer to the alpha-numeric weight-of-the-evidence classification, unit risk, the risk-specific dose or the q_1^* for cancer risk, and the RfD/RfC for health effects other than cancer, to the exclusion of other information bearing on the risk case. However, since every assessment carries uncertainties, a simplified numerical presentation of risk is always incomplete and often misleading. For this reason, the NRC (1) and EPA risk assessment guidelines (2) call for "characterizing" risk to include qualitative information, a related numerical risk estimate and a discussion of uncertainties, limitations, and assumptions--default and otherwise.

Qualitative information on methodology, alternative interpretations, and working assumptions (including defaults) is an important component of risk characterization. For example, specifying that animal studies rather than human studies were used in an assessment tells others that the risk estimate is based on assumptions about human response to a particular chemical rather than human data. Information that human exposure estimates are based on the subjects' presence in the vicinity of a chemical accident rather than tissue measurements defines known and unknown aspects of the exposure component of the study.

Qualitative descriptions of this kind provide crucial information that augments understanding of numerical risk estimates. Uncertainties such as these are expected in scientific studies and in any risk assessment based on these studies. Such uncertainties do not reduce the validity of the assessment. Rather, they should be highlighted along with other important risk assessment conclusions to inform others fully on the results of the assessment.

In many cases, assessors must choose among available data, models, or assumptions in estimating risks. Examining the impact of selected, plausible alternatives on the conclusions of the assessment is an important part of the uncertainty discussion. The key words are "selected" and "plausible;" listing all alternatives to a particular assumption, regardless of their merits would be superfluous. Generators of the assessment, using best professional judgment, should outline the strengths and weaknesses of the plausible alternative approaches.[1]

An adequate description of the process of alternatives selection involves several aspects.

a. A rationale for the choice.
b. Discussion of the effects of alternatives selected on the assessment.
c. Comparison with other plausible alternatives, where appropriate.

The degree to which variability and uncertainty are addressed depends largely on the scope of the assessment and the resources available. For example, the Agency does not expect an assessment to evaluate and assess every conceivable exposure scenario for every possible pollutant, to examine all susceptible populations potentially at risk, or to characterize every possible environmental scenario to estimate the cause and effect relationships between exposure to pollutants and adverse health effects. Rather, the discussion of uncertainty and variability should reflect the type and complexity of the risk assessment, with the level of effort for analysis and discussion of uncertainty corresponding to the level of effort for the assessment.

3. **Well-balanced risk characterizations present risk conclusions and information regarding the strengths and limitations of the assessment for other risk assessors, EPA decision-makers, and the public.**

The risk assessment process calls for identifying and highlighting significant risk conclusions and related uncertainties partly to assure full communication among risk assessors and partly to assure that decision-makers are fully informed. Issues are identified by acknowledging noteworthy qualitative and quantitative factors that make a difference in the overall assessment of hazard and risk, and hence in the ultimate regulatory decision. The key word is "noteworthy." Information that

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[1]In cases where risk assessments within an Agency program routinely address similar sets of alternatives, program guidance may be developed to streamline and simplify the discussion of these alternatives.

significantly influences the analysis is explicitly noted -- in all future presentations of the risk assessment and in the related decision. Uncertainties and assumptions that strongly influence confidence in the risk estimate also require special attention.

Numerical estimates should not be separated from the descriptive information that is integral to risk characterization. Documents and presentations supporting regulatory or site-specific decisions should include both the numerical estimate and descriptive information; in short reports, this information can be abbreviated. Fully visible information assures that important features of the assessment are immediately available at each level of review for evaluating whether risks are acceptable or unreasonable.

III. EXPOSURE ASSESSMENT AND RISK DESCRIPTORS

A. Presentation of Risk Descriptors

The results of a risk assessment are usually communicated to the risk manager in the risk characterization portion of the assessment. This communication is often accomplished through risk descriptors which convey information and answer questions about risk, each descriptor providing different information and insights. Exposure assessment plays a key role in developing these risk descriptors since each descriptor is based in part on the exposure distribution within the population of interest.

The following guidance outlines the different descriptors in a convenient order that should not be construed as a hierarchy of importance. These descriptors should be used to describe risk in a variety of ways for a given assessment, consistent with the assessment's purpose, the data available, and the information the risk manager needs. Use of a range of descriptors instead of a single descriptor enables Agency programs to present a picture of risk that corresponds to the range of different exposure conditions encountered for most environmental chemicals. This analysis, in turn, allows risk managers to identify populations at greater and lesser risk and to shape regulatory solutions accordingly.

Agency risk assessments will be expected to address or provide descriptions of (1) individual risk that include the central tendency and high end portions of the risk distribution, (2) population risk, and (3) important subgroups of the population, such as highly exposed or highly susceptible groups. Assessors may also use additional descriptors of risk as needed when these add to the clarity of the presentation. With the exception of assessments where particular descriptors clearly do not apply, some form of these three types of descriptors should be routinely developed and presented for Agency risk assessments[2]. In other cases, where a descriptor would be relevant, but the program lacks the data or methods to develop it, the program office should design and implement a plan, in coordination with other EPA offices, to meet these assessment needs. While gaps continue to exist, risk assessors should make their best efforts to address each risk descriptor, and at a minimum, should briefly discuss the lack of data or methods. Finally, presenters of risk assessment information should be prepared to routinely answer questions by risk managers concerning these descriptors.

It is essential that presenters not only communicate the results of the assessment by addressing each of the descriptors where appropriate, but that they also

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[2]Program-specific guidance will need to address these situations. For example, for site-specific assessments, the utility and appropriateness of population risk estimates will be determined based on the available data and program guidance.

communicate their confidence that these results portray a reasonable picture of the actual or projected exposures. This task will usually be accomplished by frankly commenting on the key assumptions and parameters that have the greatest impact on the results, the basis or rationale for choosing these assumptions/parameters, and the consequences of choosing other assumptions.

B. Relationship Between Exposure Descriptors and Risk Descriptors

In the risk assessment process, risk is estimated as a function of exposure, with the risk of adverse affects increasing as exposure increases. Information on the levels of exposure experienced by different members of the population is key to understanding the range of risks that may occur.. Risk assessors and risk managers should keep in mind, however, that exposure is not synonymous with risk. Differences among individuals in absorption rates, susceptibility, or other factors mean that individuals with the same level of exposure may be at different levels of risk. In most cases, the state of the science is not yet adequate to define distributions of factors such as population susceptibility. The guidance principles below discuss a variety of risk descriptors that primarily reflect differences in estimated exposure. If a full description of the range of susceptibility in the population cannot be presented, an effort should be made to identify subgroups that, for various reasons, may be particularly susceptible.

C. Guiding Principles

1. Information about the distribution of <u>individual</u> exposures is important to communicating the results of a risk assessment.

The risk manager is generally interested in answers to questions such as the following:

- Who are the people at the highest risk?
- What risk levels are they subjected to?
- What are they doing, where do they live, etc., that might be putting them at this higher risk?
- What is the average risk for individuals in the population of interest?

Individual exposure and risk descriptors are intended to provide answers to these questions so as to illuminate the risk management decisions that need to be made. In order to describe the range of risks, both high end and central tendency descriptors are used to convey the variability in risk levels experienced by different individuals in the population.

a. High end descriptor

For the Agency's purposes, high end risk descriptors are plausible estimates of the individual risk for those persons at the upper end of the risk distribution. Given limitations in current understanding of variability in individuals' sensitivity to toxins, high end descriptors will usually address high end exposure or dose (herein referred to as exposure for brevity). The intent of these descriptors is to convey estimates of exposure in the upper range of the distribution, but to avoid estimates which are beyond the true distribution. Conceptually, high end exposure means exposure above about the 90th percentile of the population distribution, but not higher than the individual in the population who has the highest exposure. When large populations are assessed, a large number of individuals may be included within the "high end" (e.g., above 90th or 95th percentile) and information on the range of exposures received by these individuals should be presented.

High end descriptors are intended to estimate the exposures that are expected to occur in small, but definable, "high end" segments of the subject population.[3] The individuals with these exposures may be members of a special population segment or individuals in the general population who are highly exposed because of the inherent stochastic nature of the factors which give rise to exposure. Where differences in sensitivity can be identified within the population, high end estimates addressing sensitive individuals or subgroups can be developed.

In those few cases in which the complete data on the population distributions of exposures and doses are available, high end exposure or dose estimates can be represented by reporting exposures or doses at a set of selected percentiles of the distributions, such as the 90th, 95th, and 98th percentile. High end exposures or doses, as appropriate, can then be used to calculate high end risk estimates.

In the majority of cases where the complete distributions are not available, several methods help estimate a high end exposure or dose. If sufficient information about the variability in chemical concentrations, activity patterns, or other factors are available, the distribution may be estimated through the use of appropriate modeling (e.g., Monte Carlo simulation or parametric statistical methods). The

[3]High end estimates focus on estimates of exposure in the exposed populations. Bounding estimates, on the other hand, are constructed to be equal to or greater than the highest actual risk in the population (or the highest risk that could be expected in a future scenario). A "worst case scenario" refers to a combination of events and conditions such that, taken together, produces the highest conceivable risk. Although it is possible that such an exposure, dose, or sensitivity combination might occur in a given population of interest, the probability of an individual receiving this combination of events and conditions is usually small, and often so small that such a combination will not occur in a particular, actual population.

determination of whether available information is sufficient to support the use of probabilistic estimation methods requires careful review and documentation by the risk assessor. If the input distributions are based on limited data, the resulting distribution should be evaluated carefully to determine whether it is an improvement over more traditional estimation techniques. If a distribution is developed, it should be described with a series of percentiles or population frequency estimates, particularly in the high end range. The assessor and risk manager should be aware, however, that unless a great deal is known about exposures and doses at the high end of the distribution, these estimates will involve considerable uncertainty which the exposure assessor will need to describe. Note that in this context, the probabilistic analysis addresses variability of exposure in the population. Probabilistic techniques may also be applied to evaluate uncertainty in estimates (see section 5, below). However, it is generally inappropriate to combine distributions reflecting both uncertainty and variability to get a single overall distribution. Such a result is not readily interpretable for the concerns of environmental decision-making.

If only limited information on the distribution of the exposure or dose factors is available, the assessor should approach estimating the high end by identifying the most sensitive variables and using high end values for a subset of these variables, leaving others at their central values.[4] In doing this, the assessor needs to avoid combinations of parameter values that are inconsistent (e.g., low body weight used in combination with high dietary intake rates), and must keep in mind the ultimate objective of being within the distribution of actual expected exposures and doses, and not beyond it.

If very little data are available on the ranges for the various variables, it will be difficult to estimate exposures or doses and associated risks in the high end with much confidence. One method that has been used in such cases is to start with a bounding estimate and "back off" the limits used until the combination of parameter values is, in the judgment of the assessor, within the distribution of expected exposure, and still lies within the upper 10% of persons exposed. Obviously, this method results in a large uncertainty and requires explanation.

b. Central tendency descriptor

Central tendency descriptors generally reflect central estimates of exposure or dose. The descriptor addressing central tendency may be based on either the arithmetic mean exposure (average estimate) or the median exposure (median estimate), either

[4]Maximizing all variables will in virtually all cases result in an estimate that is above the actual values seen in the population. When the principal parameters of the dose equation, e.g., concentration (appropriately integrated over time), intake rate, and duration, are broken out into sub-components, it may be necessary to use maximum values for more than two of these sub-component parameters, depending on a sensitivity analysis.

of which should be clearly labeled. The average estimate, used to approximate the arithmetic mean, can often be derived by using average values for all the exposure factors.[5] It does not necessarily represent a particular individual on the distribution. Because of the skewness of typical exposure profiles, the arithmetic mean may differ substantially from the median estimate (i.e., 50th percentile estimate, which is equal to the geometric mean for a log normal distribution). The selection of which descriptor(s) to present in the risk characterization will depend on the available data and the goals of the assessment. When data are limited, it may not be possible to construct true median or mean estimates, but it is still possible to construct estimates of central tendency. The discussion of the use of probabilistic techniques in Section 1(a) above also applies to estimates of central tendency.

2. Information about population exposure leads to another important way to describe risk.

Population risk refers to an assessment of the extent of harm for the population as a whole. In theory, it can be calculated by summing the individual risks for all individuals within the subject population. This task, of course, requires a great deal more information than is normally, if ever, available.

The kinds of questions addressed by descriptors of population risk include the following:

- How many cases of a particular health effect might be probabilistically estimated in this population for a specific time period?
- For non-carcinogens, what portion of the population is within a specified range of some reference level; e.g., exceedance of the RfD (a dose), the RfC (a concentration), or other health concern level?
- For carcinogens, what portion of the population is above a certain risk level, such as 10^{-6}?

These questions can lead to two different descriptors of population risk.

a. Probabilistic number of cases

The first descriptor is the probabilistic number of health effect cases estimated in the population of interest over a specified time period. This descriptor can be obtained either by (a) summing the individual risks over all the individuals in the population, e.g. using an estimated distribution of risk in the population, when

[5]This holds true when variables are added (e.g., exposures by different routes) or when independent variables are multiplied (e.g., concentration x intake). However, it would be incorrect for products of correlated variables, variables used as divisors, or for formulas involving exponents.

such information is available, or (b) through the use of a risk model that assumes a linear non-threshold response to exposure, such as many carcinogenic models. In these calculations, data will typically be available to address variability in individual exposures. If risk varies linearly with exposure, multiplying the mean risk by the population size produces an estimate of the number of cases.[6] At the present time, most cancer potency values represent plausible upper bounds on risk. When such a value is used to estimate numbers of cancer cases, it is important to understand that the result is also an upper bound. As with other risk descriptors, this approach may not adequately address sensitive subgroups for which different dose-response curve or exposure estimates might be needed.

Obviously, the more information one has, the more certain the estimate of this risk descriptor, but inherent uncertainties in risk assessment methodology place limitations on the accuracy of the estimate. The discussion of uncertainty involved in estimating the number of cases should indicate that this descriptor is not to be confused with an actuarial prediction of cases in the population (which is a statistical prediction based on a great deal of empirical data).

In general, it should be recognized that when small populations are exposed, population risk estimates may be very small. For example, if 100 people are exposed to an individual lifetime cancer risk of 10^{-4}, the expected number of cases is 0.01. In such situations, individual risk estimates will usually be a more meaningful parameter for decision-makers.

b. Estimated percentage of population with risk greater than some level

For non-cancer effects, we generally have not developed the risk assessment techniques to the point of knowing how to add risk probabilities, so a second descriptor is usually more appropriate: An estimate of the percentage of the population, or the number of persons, above a specified level of risk or within a specified range of some reference level, e.g., exceedance of the RfD or the RfC, LOAEL, or other specific level of interest. This descriptor must be obtained through measuring or simulating the population distribution.

3. **Information about the distribution of exposure and risk for different subgroups of the population are important components of a risk assessment.**

A risk manager might also ask questions about the distribution of the risk burden among various segments of the subject population such as the following: How do exposure and risk impact various subgroups?; and, what is the population risk of a

[6]However, certain important cautions apply (see EPA's Exposure Assessment Guidelines). Also, this is not appropriate for non-carcinogenic effects or for other types of cancer models. For non-linear cancer models, an estimate of population risk must be calculated using the distribution of individual risks.

particular subgroup? Questions about the distribution of exposure and risk among such population segments require additional risk descriptors.

a. Highly exposed

Highly exposed subgroups can be identified, and where possible, characterized and the magnitude of risk quantified. This descriptor is useful when there is (or is expected to be) a subgroup experiencing significantly different exposures or doses from that of the larger population. These sub-populations may be identified by age, sex, lifestyle, economic factors, or other demographic variables. For example, toddlers who play in contaminated soil and high fish consumers represent sub-populations that may have greater exposures to certain agents.

b. Highly susceptible

Highly susceptible subgroups can also be identified, and if possible, characterized and the magnitude of risk quantified. This descriptor is useful when the sensitivity or susceptibility to the effect for specific subgroups is (or is expected to be) significantly different from that of the larger population. In order to calculate risk for these subgroups, it will sometimes be necessary to use a different dose-response relationship; e.g., upon exposure to a chemical, pregnant women, elderly people, children, and people with certain illnesses may each be more sensitive than the population as a whole. For example, children are thought to be both highly exposed and highly susceptible to the effects of environmental lead. A model has been developed that uses data on lead concentrations in different environmental media to predict the resulting blood lead levels in children. Federal agencies are working together to develop specific guidance on blood lead levels that present risks to children.

It is important to note, however, that the Agency's current methodologies for developing reference doses and reference concentrations (RfDs and RfCs) are designed to protect sensitive populations. If data on sensitive human populations are available (and there is confidence in the quality of the data), then the RfD is set at the dose level at which no adverse effects are observed in the sensitive population (e.g., RfDs for fluoride and nitrate). If no such data are available (for example, if the RfD is developed using data from humans of average or unknown sensitivity) then an additional 10-fold factor is used to account for variability between the average human response and the response of more sensitive individuals.

Generally, selection of the population segments is a matter of either a priori interest in the subgroup (e.g., environmental justice considerations), in which case the risk assessor and risk manager can jointly agree on which subgroups to highlight, or a matter of discovery of a sensitive or highly exposed subgroup during the assessment process. In either case, once identified, the subgroup can be treated as a population in itself, and characterized in the same way as the larger population using the descriptors for population and individual risk.

4. **Situation-specific information adds perspective on possible future events or regulatory options.**

"What if...?" questions can be used to examine candidate risk management options. For example, consider the following:

- What if a pesticide applicator applies this pesticide without using protective equipment?
- What if this site becomes residential in the future?
- What risk level will occur if we set the standard at 100 ppb?

Answering these "What if...?" questions involves a calculation of risk based on specific combinations of factors postulated within the assessment[7]. The answers to these "What if...?" questions do not, by themselves, give information about how likely the combination of values might be in the actual population or about how many (if any) persons might be subjected to the potential future risk. However, information on the likelihood of the postulated scenario would also be desirable to include in the assessment.

When addressing projected changes for a population (either expected future developments or consideration of different regulatory options), it is usually appropriate to calculate and consider all the risk descriptors discussed above. When central tendency or high end estimates are developed for a future scenario, these descriptors should reflect reasonable expectations about future activities. For example, in site-specific risk assessments, future scenarios should be evaluated when they are supported by realistic forecasts of future land use, and the risk descriptors should be developed within that context.

5. **An evaluation of the uncertainty in the risk descriptors is an important component of the uncertainty discussion in the assessment.**

Risk descriptors are intended to address variability of risk within the population and the overall adverse impact on the population. In particular, differences between high end and central tendency estimates reflect variability in the population, but not the scientific uncertainty inherent in the risk estimates. As discussed above, there

[7]Some programs routinely develop future scenarios as part of developing a risk assessment. Program-specific guidance may address future scenarios in more detail than they are described here.

will be uncertainty in all estimates of risk. These uncertainties can include measurement uncertainties, modeling uncertainties, and assumptions to fill data gaps. Risk assessors should address the impact of each of these factors on the confidence in the estimated risk values.

Both qualitative and quantitative evaluations of uncertainty provide useful information to users of the assessment. The techniques of quantitative uncertainty analysis are evolving rapidly and both the SAB (8) and the NRC (4) have urged the Agency to incorporate these techniques into its risk analyses. However, it should be noted that a probabilistic assessment that uses only the assessor's best estimates for distributions of population variables addresses variability, but not uncertainty. Uncertainties in the estimated risk distribution need to be separately evaluated.

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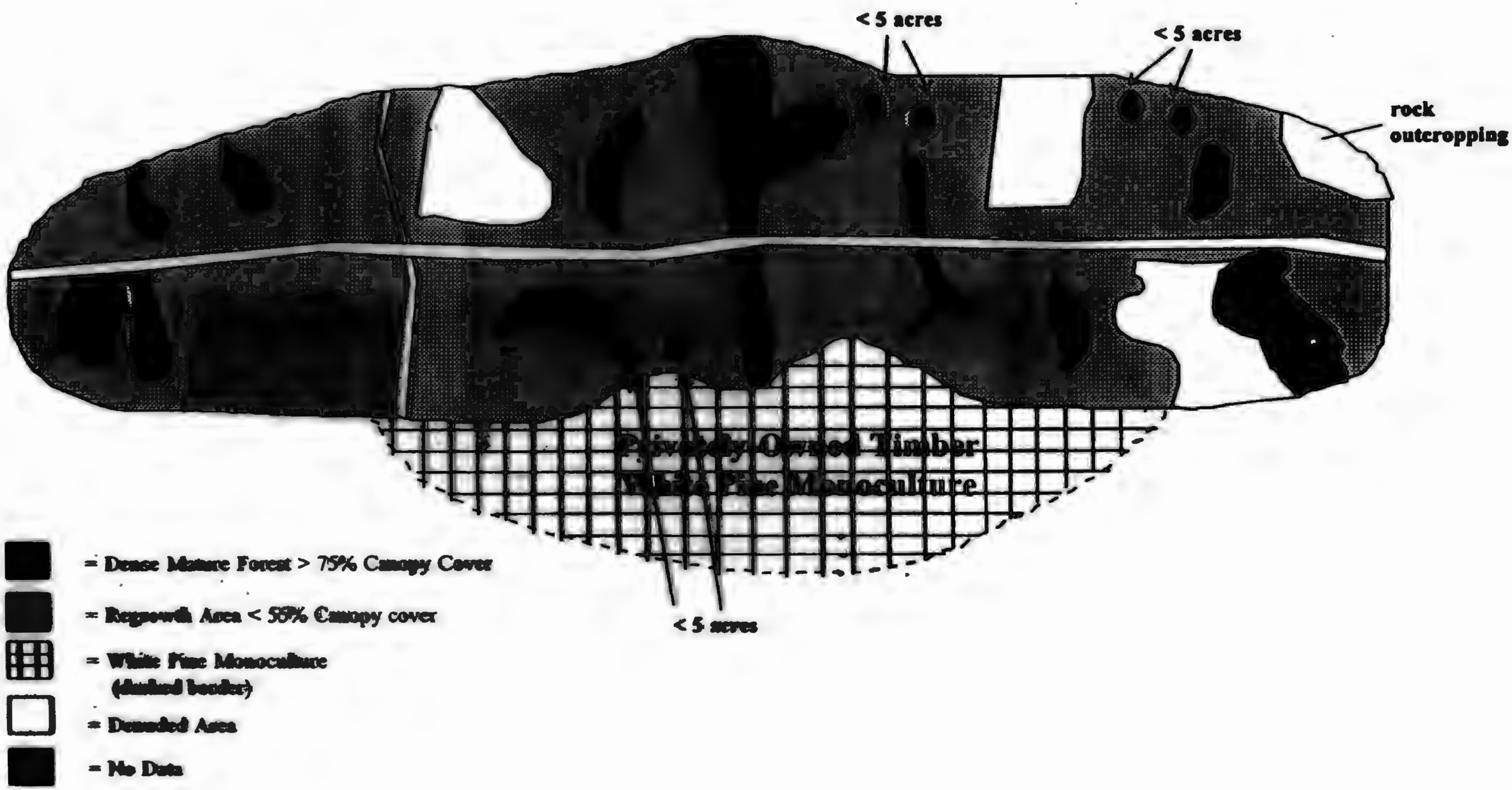
Appendix F

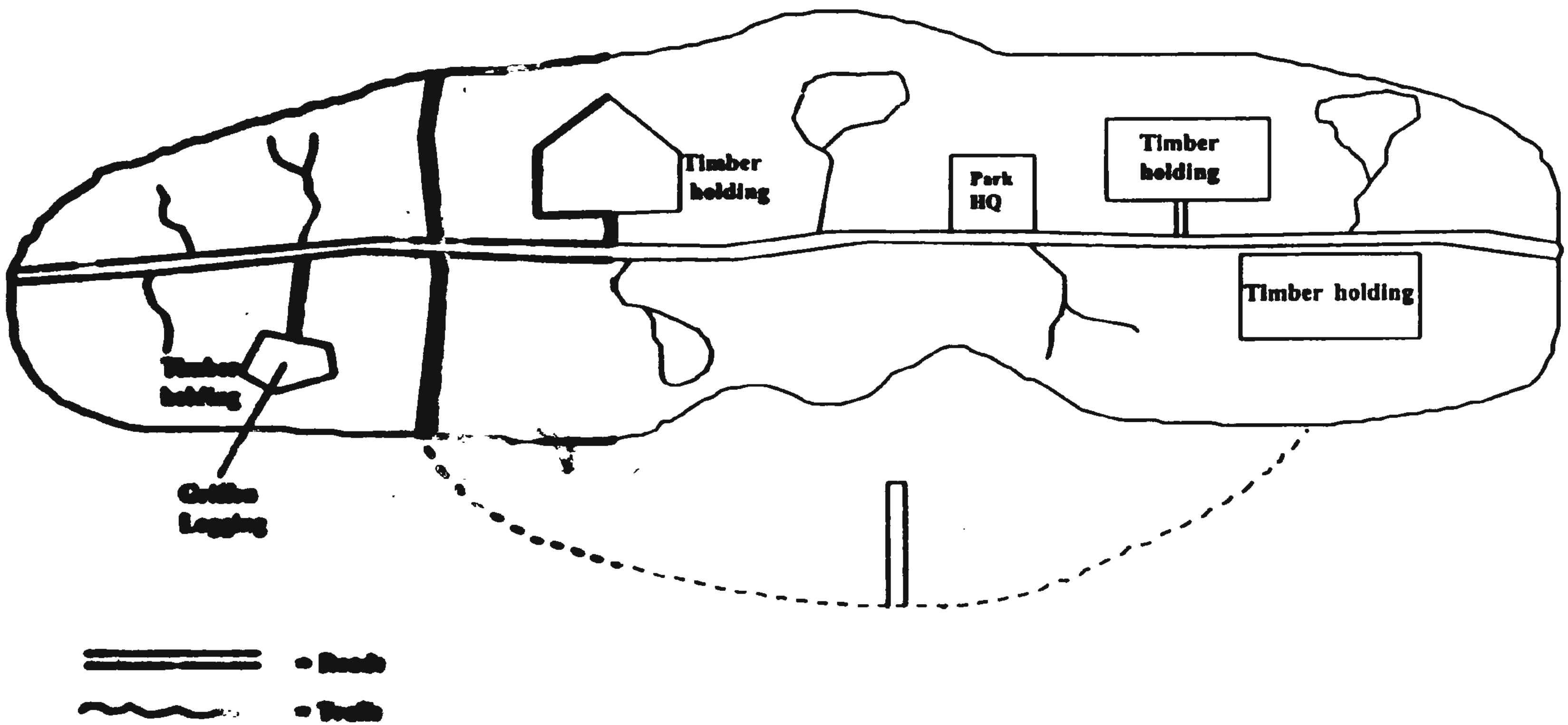
MANAGING ECOLOGICAL RISKS AT EPA; ISSUES AND RECOMMENDATIONS FOR PROGRESS

ANALYSIS INFORMATION SHEET #2
(continued)
GIS - Vegetative Cover and Type
Upland Forest Community

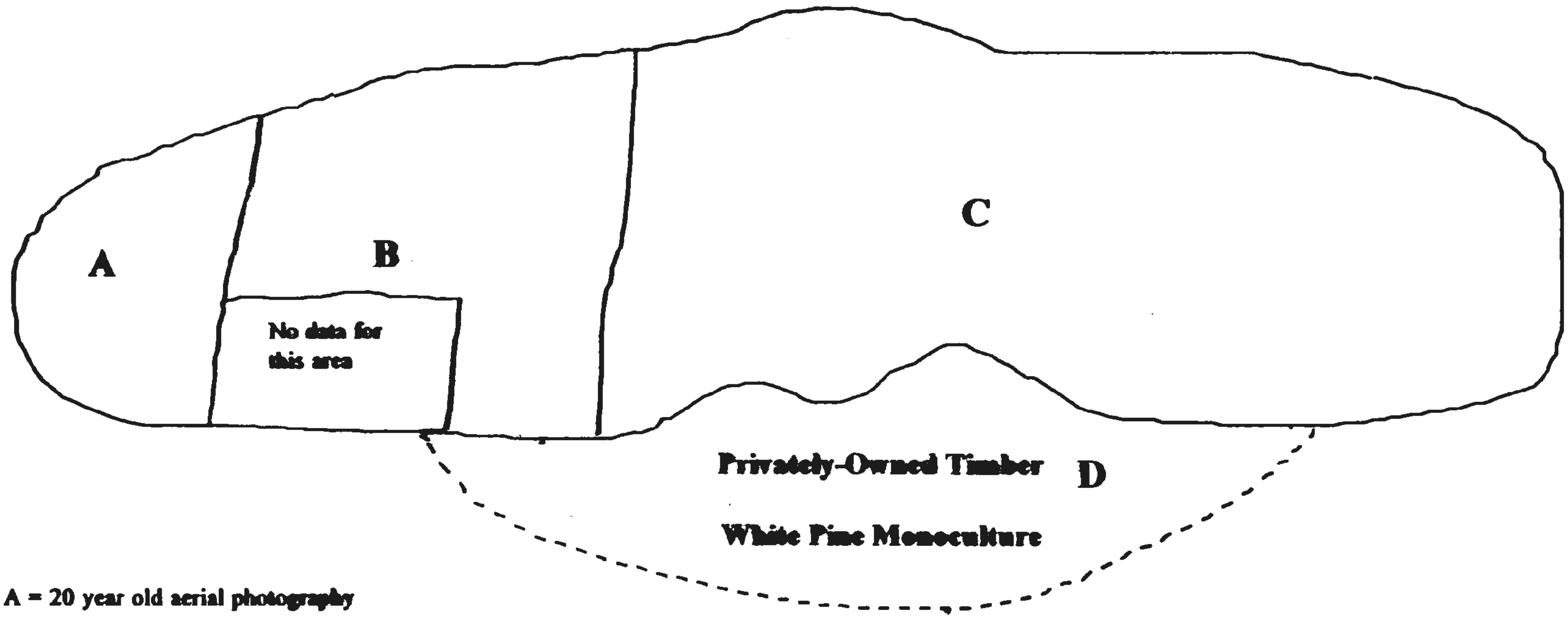


ANALYSIS INFORMATION SHEET #2

GIS - Anthropogenic Disturbances
Upland Forest Community



ANALYSIS INFORMATION SHEET #2
(continued)
GIS - Source of Data for Vegetative Cover and Type



A = 20 year old aerial photography

B = 12 year old aerial photography

C = Survey of vegetable communities of eastern half of Dan's Mt. National Forest - 2 year old aerial photography of entire eastern half of forest and extensive verification through ground surveys.

D = Survey of trees in private white pine monoculture - five year old aerial photography