Ecological Assessments in Ecosystem Management

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8. ECOLOGICAL ASSESSMENTS IN ECOSYSTEM MANAGEMENT

8.1. SUMMARY

The case studies discussed in this chapter were assessments developed to meet the needs of decision makers responsible for managing ecosystems. All of the case studies are based on an underlying concept of assessing risk. The specific studies reported range from approaches that directly derive from ecological risk assessment, as discussed in Chapter 1 of this document, to approaches that parallel many of the ecological risk assessment concepts but have no derivative linkage to ecological risk assessment. For that latter group of case studies, the assessments tended to be custom designed to address the specific of concerns of the involved managers.

Comparison of the case studies with the ecological risk assessment framework presented in Figure 1-1 indicates general alignment with the conceptual blocks of the framework, but considerably less alignment with the specific ecological risk assessment exposure to risk paradigm. All of the case study assessments involved dialogues between assessors, managers, and interested parties in the planning phase. They all involved problem formulation, but most frequently that formulation was based on providing comprehensive assessments of ecosystem processes, status, and trends. Analyses followed from the problem formulations and lead to characterization of the ecosystems involved. The results were communicated to the ecosystem managers and other interested parties, usually in the form of options for managing for a range of future ecosystem outcomes. Risk was at least implicit in assessing these outcomes, and in several of the cases it was explicitly considered. For a schematic comparison of ecological risk assessment with the ecosystem management model, Figure 1-1 may be compared with Figure 8-1. The second block in Figure 8-1 (entitled "Assessments") maps closely with the conceptual basis of ecological risk assessment.

Three sets of case studies are discussed in this chapter. The Interior Columbia River Basin Scientific Assessment was a multiagency activity aimed at providing an integrated assessment as a basis for evaluating environmental impact statement (EIS) alternatives for the ecosystems in an area that included the Columbia River Basin within the United States and east of the Cascade crest and portions of the Klamath and Great Basins in Oregon. The Southern Appalachian Assessment provided an ecological description of conditions within a region encompassing parts of seven States, extending from the Potomac River to northern Georgia and the northeastern corner of Alabama. The EPA Watershed Assessments evaluated the feasibility of applying the ecological risk assessment process as provided by the Framework for Ecological Risk Assessment (U.S. EPA, 1992) to the more complex context of watershed ecosystem management. Five watersheds were included: Big Darby Creek in central Ohio, Clinch River Valley in southwest Virginia, Middle Platte River in south central Nebraska, Middle Snake River in south central

Idaho, and Waquoit Bay on the southern shore of Cape Cod. Each of these assessments involved an integrated ecosystem approach to making land management decisions.

The role of science in these assessment activities, as in risk management, is to provide objective information for decision making. That information is framed in a manner that meets the needs of decision makers, while strictly maintaining scientific objectivity, integrity, and quality control. Decision maker needs are agreed upon in an interactive process between decision makers and assessment managers. Although new research is seldom performed within the assessment activity, synthesis of existing information often provides new knowledge or perspectives about the ecosystems being assessed. In all of the case studies reported in this chapter, science played a critical role in facilitating definition of the pertinent management questions to be addressed, establishing information on which to build the assessments, maintaining quality control and assurances protocols, analyzing and synthesizing information, and working to communicate results to responsible managers and interested parties.

> Christensen et al. (1996) defines ecosystem management as "...management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of ecological interactions and processes necessary to sustain ecosystem composition, structure and function."

8.2. INTRODUCTION

Ecological risk assessment is a process of organizing and analyzing data, information, assumptions, and uncertainties to evaluate the likelihood of adverse ecological effects (U.S. EPA, 1996). Ecosystem management is a process for maintaining the integrity of ecosystems over time and space (Quigley et al., 1996a). Ecosystem sustainability increasingly is being stated as the goal of ecosystem management. A variety of ecosystem assessments have been led by Federal agencies in recent years. These assessments were intended to help decision makers and other interested parties better understand and evaluate consequences of potential regulatory or natural resource allocation actions within a larger social, economic, and ecological framework. This chapter provides information on the ongoing development of the ecological risk assessment process and the ecosystem management assessment process. The linking of these two processes can bring improved organizational and analytical consistency to the assessment of information in support of multiple scales of resource planning and decision making needed for ecosystem management. The intent of this chapter is to promote dialogue between the two communities and enhance cross-community appreciation of needs and approaches.

Section 8.2 of the chapter presents an overview of several ecosystem assessments done in recent years. Section 8.3 provides several Agency case study illustrations of assessment approaches. Section 8.4 discusses risk assessment methodology development. Section 8.5

examines ecological risk assessment in the ecosystem decision-making context. Section 8.6 discusses possible next steps, beginning with a description of cost-benefit considerations followed by suggestions for expanded use of the proposed EPA ecological risk assessment guidelines in ecosystem assessments; the section concludes with an analysis of technical and research challenges.

A fundamental challenge to ecosystem management is the need to understand and manage complex ecosystems simultaneously across large and small temporal and spatial scales (Quigley et al., 1996a). In light of this challenge, decision makers are faced with making complex social, economic, and environmental decisions. These decisions bring with them an inherent level of uncertainty for decision makers and stakeholders alike. Decision makers and stakeholders need to recognize this inherent uncertainty and be flexible enough to adjust their decisions in the face of surprise. A general planning model for ecosystem management was put forward by Quigley et al (1996a) (Figure 8-1). The process has four basic parts: monitoring, assessments, decision, and implementation.

Ecological risk assessments are tools decision makers can use to help identify and, it is hoped, reduce uncertainty throughout the decision-making process. Ecosystem assessments are also tools to help decision-makers. Ecosystem assessments follow general concepts as shown in Figure 8-1, but they do not have an existing set of definitional rules. The general concepts include acknowledgment of stakeholders and their questions, development of situational analyses, identification of trade-offs and limits, development of an understanding of future conditions, and assessment of risk for issues of concern. The primary reason for conducting ecosystem assessments then is to provide a framework for decision makers and stakeholders to help them understand and evaluate the consequences of actions with respect to regulation and/or allocation of natural resources within the larger social, economic, and ecological context. The ecosystem management process presented in Figure 8-1 outlines several sections where ecological risk assessment can link with ecosystem management. In the assessments section of the process, assessing risks for issues of concern is presented. In ecological risk assessment, risk characterization involves addressing the likelihood and consequences, weight of evidence, uncertainty, and other factors. For determining the impact of a stressor, multiple stressors, or a management scenario, a qualitative or quantitative analysis of the likelihood and consequences of the scenario would be valuable for the decision makers. Supporting the "how sure are we of this"

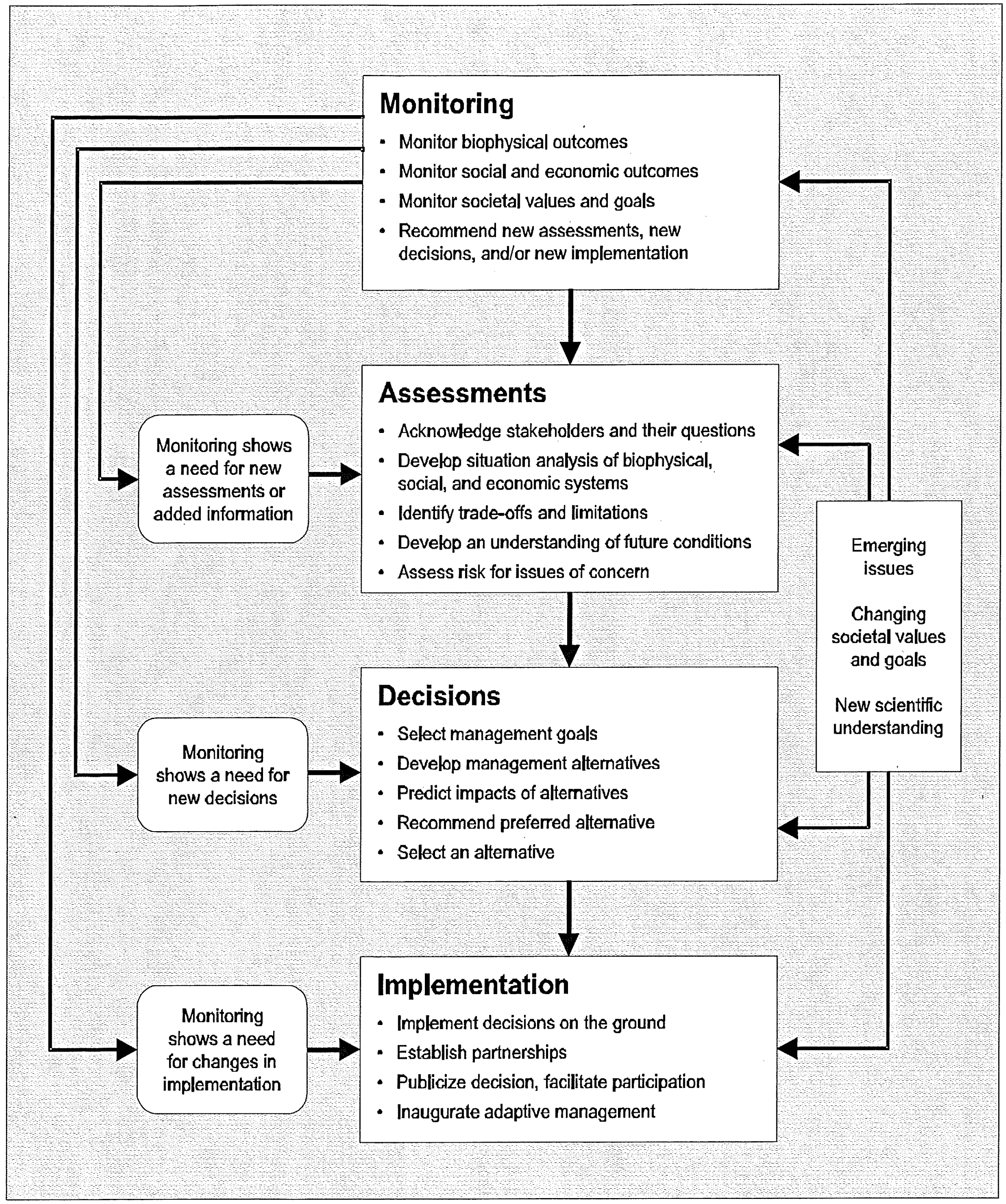

Figure 8-1. Ecosystem management model. Each step has several parts. Because the model is iterative, external or internal influences can initiate any step in the process, and the process never ends.

Source: Quigley et al., 1996a.

question, uncertainty and lines-of-evidence analyses provide additional information to the managers. In the decisions section of the ecosystem management process, the prediction of impacts from alternatives is presented. Prediction of the likelihood and consequences of a management action on an ecological system can utilize ecological risk assessment methods. Chapter 4 presents an effective process for nonindigenous species that could be adapted for multiple stressors or management alternatives.

It is within this context of ecosystem management, uncertainty, and adaptation that a series of "lessons learned" workshops, designed as an adaptive learning approach to ecoregional assessments, are being conducted to discuss and document the knowledge gained by various assessment teams throughout the country.

The first iteration of ecosystem assessments, which include the Report of the Forest Ecosystem Management Assessment Team, the Columbia River Basin Assessment, and the Sierra Nevada Ecosystem Project, were mandated by the President. These were generally high-cost projects ($6 million to $36 million) directed at a number of high-profile issues in the Pacific Northwest and Northern California.

Second-generation ecosystem assessments were chartered by decision makers (Forest Service Regional Foresters) for the purpose of providing state-of-the-art information needed to revise forest land management plans. These are best represented by the recently completed Southern Appalachian Assessment, the ongoing Great Lakes Assessment, the Northern Great Plains Assessment, and the Ozark/Ouachita Highlands Assessment. These are low-cost alternatives ($0.5 million to $2 million) to the earlier generation noted above.

Key findings from the "lessons learned" workshops are summarized below (USDA, 1996).

- The assessment process
  - —Assessments are not decision-making documents. However, they do provide a synthesis of information in support of multiple scales of resource planning and decision making.
  - —Assessments should be issue driven.
  - —Data synthesis and acquisition need to be strongly focused on the assessment issues.
  - —Preassessment planning is critical to conducting an assessment.
  - —Process, structure, and function are the ecosystem components evaluated during the assessment process. These components need to be analyzed at multiple spatial and temporal scales.
  - —Broad-scale assessments are a rich source of new information. Recognizing emergent properties of ecosystems at broader scales is an important part of this new information.

- Linkages to other assessments and programs

  —There is a need to develop implementation, effectiveness, and validation monitoring programs at multiple scales. These programs should update assessment information over time.

  —Ecoregional assessments can be linked using common information themes and protocols.

  —Cooperation with the Federal Geographic Data Committee will help ensure data linkages among other national, regional, and landscape assessments.

- Public involvement and partnerships

  —Public participation for ecoregional assessments should be based on adaptive management principles focused on achieving awareness and active involvement of a diverse array of stakeholders.

  —Public involvement is crucial to the success of assessments and provides benefits in later decision-making forums.

  —Because of their sheer size and the complexity of ownership patterns, ecoregional assessments have a greater need for partnerships than any other planning process.

- Assessment products

  —Assessments produce various tangible and intangible products, including findings, data, maps, references, changed relationships with participating agencies and the public, and institutional and organizational change. Products that address immediate needs and issues are most likely to get immediate use.

- Information management

  —An interagency commitment needs to be made to ensure maintenance of data, maps, meta data, etc., for future assessment and monitoring efforts.

  —Establishing an information management infrastructure before the assessment should be a high priority.

8.3. CASE STUDIES AND EXAMPLES

8.3.1. Interior Columbia River Basin Scientific Assessment[8]

The Interior Columbia River Basin Ecosystem Management Project was initiated by the Forest Service (FS) of the U.S. Department of Agriculture and the Bureau of Land Management (BLM) of the U.S. Department of the Interior in response to decisions to adopt an ecosystem-based management strategy; the need to replace interim direction; concerns about declining forest, rangeland, and aquatic health; and concerns about single-species approaches to conservation and management. The project area includes those portions of the Columbia River Basin within the United States and east of the Cascade crest and portions of the Klamath and Great Basins in Oregon (the Basin). The primary products called for in the charter include (1) a framework for ecosystem management (Haynes et al., 1996), (2) an integrated scientific assessment (Quigley et al., 1996a; Quigley and Arbelbide, 1996), (3) two environmental impact statements (EISs) addressing management of FS- and BLM-administered lands within the Basin, and (4) an evaluation of the EIS alternatives (Quigley et al., 1996b). The framework, assessment, and evaluation of alternatives are products of the science team, and the EISs are products of the EIS teams. In addition to these primary products, more than 40 scientific publications are expected from this work over the next several years. The following material is drawn mostly from the executive summaries of the science documents cited above. The Basin includes 145 million acres, with the FS and BLM administering more than one-half (76 million acres) of the area. This sparsely populated area covers portions of 7 States and 100 counties. It encompasses a variety of climatic, topographic, socioeconomic, forest, and rangeland conditions. It extends from the Continental Divide on the east to the Cascade crest on the west. It includes resources of international significance such as Yellowstone National Park and Hells Canyon. It is home to some 22 Native American Indian tribes and more than 3 million people.

8.3.1.1. *Framework*

With the announcement by the FS and BLM of the intent to adopt an ecosystem-based strategy came the need to frame the interactions among decisions at multiple levels and their relationship with assessments. The framework assumes that the purpose of ecosystem management is to maintain the integrity of ecosystems over time and space. It is based on four ecosystem principles: ecosystems are dynamic, can be viewed as hierarchies with temporal and spatial dimensions, have limits, and are relatively unpredictable. This approach recognizes that people are part of ecosystems and that stewardship must be able to resolve tough challenges,

[8]This section provides examples of a range of assessments prepared by a number of agencies. The views expressed represent those of the authors of each assessment summary.

including how to meet multiple demands with finite resources. The framework describes a general planning model for ecosystem management (Figure 8-1) that has four iterative steps: monitoring, assessment, decision making, and implementation. Since ecosystems cross jurisdictional lines, the implementation of the framework depends on partnerships among land managers, the scientific community, and stakeholders. It proposes that decision making be based on information provided by the best available science and the most appropriate technologies for land management.

8.3.1.2. *Integrated Scientific Assessment*

This integrative assessment links landscape, aquatic, terrestrial, social, and economic characterizations to describe biophysical and social systems. Integration was achieved through the use of a framework built around six goals for ecosystem management and three different views of the future. The assessment represents the largest and most comprehensive assessment of ecosystems undertaken. The overall purpose of the assessment is to develop a better understanding of the current, historical, and potential future biophysical, economic, and social conditions and trends in the Basin. The assessment is not a decision document nor does it resolve specific resource issues. Rather, the assessment provides the foundation for proposed additions or changes to existing FS and BLM resource management plans to consistently manage risks and opportunities at multiple scales. Some highlights of the findings include the following:

- There has been a 27% decline in multilayer and a 60% decline in single-layer old-forest structures from historical levels, predominantly in ponderosa pine and Douglas-fir forest types.
- Aquatic biodiversity has declined through local extirpations, extinctions, and introduction of exotic fish species, and the threat to riparian plants and animals has increased.
- Some watershed disturbances, both natural and human induced, have caused and continue to cause risks to ecological integrity, especially owing to isolation and fragmentation of fish habitat.
- The threat of severe lethal fires has increased by nearly 20%, predominantly in the dry and moist forest types.
- Rangeland health and diversity have declined because of exotic species introductions, historical grazing, changing fire regimes, agricultural conversions of native shrublands and herblands, and woodland expansion in areas that were once native shrublands and herblands.
- Human communities and economies of the Basin have changed and continue to change rapidly, although rates of change are not uniform.

There are tremendous opportunities to restore ecosystem processes and functions as well as provide for the flow of goods and services demanded by society. In addition to tremendous opportunities, risks are also associated with attaining these opportunities. Some risks are related to natural events such as wildfire, insect, and disease outbreaks, while other risks are associated with management activities such as road building, timber harvest, and prescribed fire. These risks and opportunities vary greatly across the Basin. The assessment has characterized the broad-level risks and opportunities across the Basin. Realizing the opportunities and managing the risks involves working within the adaptive management framework presented.

8.3.1.3. *Ecosystem Integrity*

Drawing from the detailed assessment of historical and current conditions within the Basin, two concepts were used to integrate the major functional areas to determine status of the ecosystems. Maintaining the integrity of ecosystems is assumed to be the overriding goal of ecosystem management. The integrity of ecosystems encompasses both social and biophysical components; the health of the Basin's people and economy is not a separate issue from the health and integrity of other ecosystem components. Ecological integrity refers to the presence and functioning of ecological components and processes. The basic components of ecological integrity include the forest, range, and aquatic systems, with a hydrologic system that overlays the landscape as a whole. The counterpart to ecological integrity is socioeconomic resiliency (measured at the county level), which in the context of ecosystem management reflects the interests of people to maintain well-being through personal and community transitions.

8.3.1.4. *Composite Ecological Integrity*

Integrity ratings were developed for five ecological components: forestland, rangeland, forest and rangeland hydrologic, and aquatic systems. This information became the primary basis for estimating composite ecological integrity for each subbasin (approximately 850,000 acres in size) within the Basin. Currently, 16% of the Basin is rated as having high relative composite ecological integrity, 24% as moderate, and 60% as low. Eighty-four percent of the systems with high integrity are on FS- and BLM-administered lands, while 39% of the low-integrity systems are on FS- and BLM-administered lands.

8.3.1.5. *Socioeconomic Resiliency*

Socioeconomic resiliency, estimated at the county level for this analysis, dealt with the adaptability of human systems. High ratings imply that these systems are highly adaptable; changes in one aspect are quickly offset by self-correcting changes in other sectors or aspects.

High levels of socioeconomic resiliency should reflect communities and economies that are adaptable to change, where sense of place is recognized in management actions, and where the mix of goods, functions, and services that society wants from ecosystems is maintained. A low rating applies to 54 Basin counties. Another 20 Basin counties were rated as having an intermediate level of resiliency. A high socioeconomic resiliency rating applies to the 26 Basin counties that are more densely populated. While 68% of the area within the Basin is rated as having low socioeconomic resiliency, 67% of the people of the Basin live in areas with high socioeconomic resiliency.

8.3.1.6. *Findings From the Future Management Options*

The current draft EIS has primarily considered three options: (1) continuation of current approaches, (2) restoration emphasis, and (3) reserve area emphasis. Evaluations of the options benefitted from the underlying science documents and assessments conducted in the basin. The public comment period on the draft EIS has closed. Land managers and stakeholders will now engage in a dialog about the content and process of selection of the preferred strategy for managing the FS- and BLM-administered lands.

8.3.2. The Southern Appalachian Assessment

The Southern Appalachian Assessment (SAA) is an ecological description of conditions within a region encompassing parts of seven States. The area extends southward from the Potomac River to northern Georgia and the northeastern corner of Alabama. The SAA assembles the best available knowledge about the land, air, water, and people of the region. The SAA does not specifically apply typical risk assessment tools. It does attempt to describe change in the environment and the stresses that affect it. It is similar to risk assessment in that it avoids recommending actions.

The recently completed assessment was not the first. Early in the 20th century, the Appalachian landscape and its natural resources had been badly abused by destructive agricultural practices and exploitive logging. In 1901, at the request of the U.S. Congress, the Department of Agriculture conducted a similar assessment for the region. Its findings led to the Weeks Act, which authorized the establishment of national forests and national parks in the eastern United States.

Although there was no specific statutory requirement for the latest assessment, national forest management plans required by the 1976 National Forest Management Act had been in place for more than 10 years and needed to be revised. The management of national forests and other Federal lands is directly influenced by the biological, social, and economic conditions that surround them. Also, Federal and State regulatory agencies were concerned that increasing population pressures and economic development were adversely affecting environmental quality in the region. Thus, there was a need for a comprehensive and credible source of information to serve as a basis for planning.

Even before the SAA got under way, Federal and State agencies in the Southern Appalachian region had worked together on several projects of mutual interest. A coordinating group had been established, initially to address land management problems, but later expanded to include most environmental issues within the area. This was the Southern Appalachian Man and Biosphere (SAMAB) program. SAMAB now includes 12 Federal and 3 State agencies. Through the coordination of the SAMAB program, most of these agencies were involved in some way in conducting the SAA.

The SAA began in the spring of 1994. A dialog that involved SAMAB agencies and forest planners outlined a number of issues that needed to be addressed. There was no single issue producing conflict or confrontation, but there was widespread concern for the health and welfare of the region's resources. Starting with an initial set of issues, a series of public meetings was held at different locations within the area. People were told about the assessment that was planned and asked about their concerns and suggestions. The issues and concerns became the basis for a set of questions that the assessment would address.

The SAA was organized around four major environmental components: air, land, water, and people. Interagency teams were established to address each of these themes. An initial evaluation of the data indicated the need for a strong emphasis on map-based geographic information system technology. An interagency policy group was formed to guide the assessment. One of the group's first functions was to establish constraints or targets for the time of completion, money and people available, size of reports, and sources of data. Early in the process, it was decided to invite the public to attend and participate in most aspects of the assessment.

Each of the four major topics making up the assessment culminated in separate technical reports (atmospheric, aquatic, terrestrial, and social/cultural/economic reports). Although the analyses differ, the reports have several common features. Each starts with a set of questions that were derived from the issue identification process. The questions served to guide the analysis and to define the scope of the assessment. In addition, each interagency team was asked to describe the current resource situation and, to the extent possible, look for past and future trends in resource condition. Part of the assessment also consisted of evaluating the quality of available data sources and documenting future research and monitoring needs. The following paragraphs give a brief summary of each assessment topic.

The atmospheric team concentrated its analysis on nitrogen oxide, sulfur dioxide, particulate matter, and volatile organic compounds. These pollutants are important because the secondary pollutants formed from them are suspected of reducing visibility, producing ozone, and having consequent impacts on vegetation and human health; the pollutants also are important because of the acid deposition impacts on terrestrial and aquatic environments. In addition, these are the pollutants directly affected by the Clean Air Act legislation. The report describes the location of emissions and concentrations where emissions are greatest, and it projects likely future trends. Visibility is especially important in the SAA analysis because the Clean Air Act established as a national goal the "prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class 1 Federal areas where impairment results from man-made pollution." The majority of the visibility data was obtained in the seven Class 1 areas within the SAA region.

The terrestrial report is divided into two separate sections: (1) plant and animal resources and (2) forest health. The report responds to the considerable interest in the status of threatened, endangered, or sensitive species. Of more than 25,000 species known to inhabit the area, 472 were given special attention. The group includes 51 species that are federally listed as threatened or endangered and 366 whose numbers are sufficiently restricted that their populations are considered at risk. Most of these species can be grouped into 19 associations based on similar habitat requirements. Historically, the most significant event to affect the region's forests was the initial logging that was largely accomplished in the early decades of this century. Perhaps equally profound, although less dramatic, are the effects of a number of forest health factors. The chestnut blight, gypsy moth, and dogwood anthracnose have altered species composition of the region's forests. Other recently discovered diseases such as hemlock woolly adelgid and butternut canker are also cause for concern. Although historic data are inconclusive, it seems clear that the most serious threats to the health of the region's forests are coming from exotic pests introduced from other parts of the world.

The headwaters of nine major rivers lie within the boundaries of the Southern Appalachians, making it the source of drinking water for most of the Southeast. The aquatic assessment compiled the best available data on water resource status and trends, riparian condition, impacts of various land management or other human activities, water laws, aquatic resource improvement programs, and water uses. The report discusses the distribution of aquatic species and identifies some problems, including degraded streams, eutrophication of lakes, and the impacts of increasing human population and development. There is general agreement, however, that water quality has improved significantly since the adoption of the Clean Water Act in 1972.

Humans are a part of the ecosystem. Natural resource values are derived from the utility and aesthetic or intrinsic benefits that come from human culture. The social/cultural/economic assessment looked at four aspects of human influence: (1) communities and human influences, (2) the timber economy, (3) outdoor recreation, and (4) roadless and designated wilderness areas.

The relationship between people and public lands in the Southern Appalachians has changed greatly during the past two decades. The growing economy has become more diverse and less dependent on manufacturing. Newcomers to the region, many of them retirees, resort owners, or those employed in service industries, are more interested in scenery and recreation than in resource extraction. Also, the increasing population throughout the area is fragmenting land use and ownership, with adverse effects on wildlife habitat and timber availability. These changes are reflected in diverse, and often incompatible, demands on public lands. The assessment was aimed at better understanding the public and how their collective values have changed in recent years. This should be useful to both land managers and community planners.

The SAA documents consist of four technical reports and a summary report. But equally important are two other products of the assessment. The first is a set of five computer disks (CD-ROMs) that contain all the maps and data used in the assessment in digital form. These were distributed to the 400 selected Federal Depository Libraries used by the U.S. Government Printing Office and to individuals who requested them. The second medium is the Internet. In-depth versions of the text and data are available on the SAMAB, Forest Service, and Info South home pages on the World Wide Web (WWW).

The spirit of the SAA can best be summarized by a quotation from the documents: "The Southern Appalachian Assessment was accomplished through the cooperation of federal and state natural resource agency specialists. The strong emphasis placed on working together toward a common goal is increasingly recognized as essential to effective government operation. Teamwork has strengthened our understanding and communication. With the assessment as a framework for future action, government policy and management can become more consistent and better coordinated." This basic principle is being applied as various groups work to further apply the information contained in the SAA.

8.3.3. EPA Watershed Assessments

EPA, other Federal and State agencies, environmental groups, and communities are placing increasing emphasis on community-based environmental protection and integrated ecosystem management. This emphasis arises from a recognition that the impacts of multiple human activities combine in the environment to cause significant adverse ecological effects that are not amenable to regulation under current environmental law. Unless these stressors are managed at the community level, local and national environmental goals may not be achievable. As the Agency shifts emphasis from command and control toward voluntary compliance and community-based environmental protection, it becomes critical that EPA provide the scientific basis for community-level management decisions. States and local organizations need a process and tools they are able and willing to use for determining what ecological resources are at risk and how best to protect those resources through management action. Case studies for evaluating risk to watershed ecosystems were initiated to develop examples and guidance on how to use science more effectively in ecosystem management.

8.3.3.1. *Background*

The watershed ecological risk assessment case studies were initiated in September 1993 to evaluate the feasibility of applying the ecological risk assessment process as provided in the Framework for Ecological Risk Assessment (U.S. EPA, 1992) to the more complex context of watershed ecosystem management. The Risk Assessment Forum and the Office of Water agreed to jointly sponsor the development of prototype ecological risk assessment case studies in watersheds under the guidance of a Risk Assessment Forum technical panel. The case study watersheds served as natural laboratories where teams used the process of ecological risk assessment to address ecosystem-level problems concerning diverse stressors, ecological values, and political and socioeconomic concerns in watersheds of different type, size, and complexity. The case studies served as a mechanism for learning about key management and research questions, limitations to the risk assessment process provided in the framework report, and issues surrounding involvement by interested parties that must participate in resource management.

Watershed ecosystems were chosen as the landscape unit for ecological, pragmatic, and programmatic reasons: (1) Watersheds are natural geomorphological units with definable boundaries where water flows across the landscape and collects in surface water bodies and groundwater. Because water flows across a landscape, the effect of human impacts occurring on land and directly in the water become combined as water flows toward collection basins such as rivers, lakes, wetlands, and estuaries, thus providing an effective landscape unit to assess the combined and cumulative effect of multiple stressors. (2) Watershed ecosystems are highly flexible in size. The size defined is based on the type of issues and relevant management decisions. A small community may be interested in the watershed in its valley and may focus management efforts at its level of influence, even though its watershed is part of a larger system. A State may choose to focus on a watershed that covers one-quarter of the State in order to organize permitting activities. Multiple States may become involved in cooperative management of large watersheds that cross political boundaries. Thus, watersheds can be local or regional in scope, and can cover multiple ecologically diverse regions. (3) Clean abundant water will increasingly become a highly valued limiting resource, both for direct human use and for supporting ecosystems. (4) EPA is encouraging States to organize regulatory and nonregulatory efforts according to watershed boundaries. This is intended to focus efforts in such a way as to promote the coordination of management efforts to improve environmental protection and reduce management cost. Geographic areas defined by a watershed are not appropriate for all environmental problems requiring management. The type of assessment question being asked determines the rationale for defining landscape boundaries. For example, a watershed would be appropriate for addressing risk to aquatic resources within a surface water body but would not be effective for concerns about air pollution in a forest ecosystem that covers parts of several watersheds. Although the case studies are focused on watershed ecosystems, the project's focus is on the process of conducting risk assessments for ecosystem-level problems. This process is readily adaptable to other ecosystem management problems.

8.3.3.2. *Process*

The case studies were initiated in 1993 through joint sponsorship by the Office of Water and the Office of Research and Development and administered under the Risk Assessment Forum through a technical panel.

8.3.3.3. *Watershed Case Study Selection*

Early in 1993, a solicitation for candidate watersheds for the project was announced and resulted in more than 50 applications. Watersheds were selected for the project on the basis of specific selection criteria, including data availability, identification of local participants, diversity of stressors, and significant and unique ecological values. The watersheds selected represent different surface water types; an array of chemical, physical, and biological stressors; and a diversity of valued ecological resources, scales, management problems, socioeconomic circumstances, and regions. Case study teams were established and began work in September 1993.

8.3.3.4. *Case Study Teams*

Each case study is being developed by an interdisciplinary, interagency team of scientists and natural resource managers. Professionals recruited for the teams include EPA scientists and managers from regions and program offices, State scientists and regulators, and scientists from other Federal agencies, nongovernmental groups, industry, and academia. When forming teams, every effort was made to recruit individuals with expertise in ecological risk assessment, ecological processes, the ecological resources and stressors in the targeted watershed, and ecosystem management. Recruitment has been a continuing process throughout development. Team size ranges from 10 to 50 members and participants, and other professionals are consulted as needed. The teams hold regular meetings (normally by conference call), and all teams have met in the watershed as part of the work on the case study.

8.3.3.5. *Characteristics of Selected Watersheds*

Five watersheds were selected for the project: Big Darby Creek in central Ohio, Clinch River Valley in southwest Virginia, Middle Platte River in south central Nebraska, Middle Snake River in south central Idaho, and Waquoit Bay on the southern shore of Cape Cod in Massachusetts. These watersheds are diverse in size, type, ecological characteristics, stressors, and socioeconomic context. Although ground water is an important element in several of the case studies and is addressed in the assessments, the watershed boundaries were defined by surface water flow. Only the Big Darby Creek and Waquoit Bay case studies include the hydrologic boundaries of an entire watershed. The Clinch River Valley includes most of the watershed as defined by topography, but the southern part of the watershed was inundated because of dam construction and the reservoir is excluded. Both the Middle Snake River and Middle Platte River watershed case studies are based on important middle segments of the rivers but do not attempt to consider the very large watershed system of which they are a part.

Big Darby Creek is a medium-sized river system in a relatively flat agricultural landscape that is considered to be of high quality. One of the Nature Conservancy's Last Great Places, it contains highly diverse communities of fish and mussels, good riparian areas, and clean water. Agricultural management practices and urban and suburban encroachment are placing these values at risk. The local community is interested in better land use planning and management practices to prevent degradation.

The Clinch River Valley contains highly valued fish and mussel communities and includes the greatest diversity of mussels in North America, many of which are rare and endangered. The valley is also a Last Great Place, but agricultural practices and mining are major stressors in the high-relief terrain environment. Protection of these valued resources must be done in a socioeconomically depressed area.

The Middle Platte River wetlands support millions of birds migrating in the Central Flyway, including the endangered whooping crane, as well as many resident species. Competition for water in the Middle Platte River, part of our Nation's breadbasket, is a politically charged issue. Hydrological modifications have changed the broad-braided river wetlands of the Middle Platte to a 50-mile stretch of narrowed wetland systems.

The Middle Snake River, once charged by natural springs bursting from canyon walls, is now primarily fed by irrigation return flows. Considered the most impaired watershed among the case studies, the Snake River has become an algae- and sediment-choked stream in many parts of its reach. Better management of dams, irrigation return flows, sediments, and trout hatcheries is central for protecting and restoring at least part of the river's function.

Waquoit Bay is the smallest watershed among the case studies, valued for its aesthetic beauty, recreational opportunities, and commercial fisheries. Currently, residential development, a

Superfund site, and other activities in the watershed are placing these values at risk. The fairly affluent community is seeking ways to reverse degradation and regain ecological values.

8.3.3.6. *Resources to Support Case Study Development*

The case studies were designed to demonstrate what can be accomplished using available data and limited resources. The project was organized to approximate the kinds of expertise, resources, and data likely to exist in communities that would be responsible for using guidance for implementing ecosystem management at the community level. The following statements characterize case study resources:

- Members and participants on watershed teams are professionals from diverse disciplines whose time was volunteered by their organizations for the effort.
- A small minority of participants were familiar with risk assessment.
- Each watershed ecosystem is being evaluated within the context of many competing socioeconomic and political concerns.
- The case studies are being conducted with minimal funding and a reliance on existing data.

8.3.3.7. *Lessons Learned*

The watershed ecological risk assessment case studies were developed using available guidance on ecological risk assessment as presented in the framework report (U.S. EPA, 1992). During case study development, several adjustments to this process were found to be valuable. Each team's experiences added dimension to our interpretation about what adjustments were needed. Sometimes teams experienced successes, sometimes readjustments and redirection. All were important learning opportunities.

We believe that the process that emerged from the case studies is sound and valuable and will be the focus of detailed guidance in the future. However, all of the lessons learned are now incorporated at a general level in the Agency's Draft Proposed Guidelines for Ecological Risk Assessment (U.S. EPA, 1996). Specific issues and changes that emerged from conducting the case studies include how value-initiated risk assessments alter the process of problem formulation, the importance and process of "planning" for establishing ecosystem management goals, how to develop and interpret management goals for an ecosystem-level risk assessment, how to select and define assessment endpoints, how to develop conceptual models for watershed ecosystems with multiple stressors, when and how to define measures and data that will be used in the assessment, and the explicit need for analysis plans.

8.3.3.8. *Reviews and Current Status*

In May 1994, the Risk Assessment Forum Ecorisk Oversight Committee held a peer review of the draft problems formulations. Substantial discussion at that review centered on the generation of management goals for the watershed and their interpretation into assessment endpoints. The Risk Assessment Forum organized a second peer review in September 1994 that focused on the analysis plans generated from conceptual model development. Significant discussion centered on aspects of the risk assessment process that were changing as a result of case study development. Throughout development, case study drafts have undergone technical peer review by independent professionals knowledgeable about the watershed. In July 1996, the "process" and "lessons learned" and draft "planning and problem formulation" sections of the five case studies were presented to the EPA Science Advisory Board (SAB) for advice on work in progress. The results of that peer review are published and available to the public on the SAB Website (http://www.epa.gov/sab) as report number EPA-SAB-EPEC-ADV97-001. Based on feedback, the case study teams continue to refine work on problem formulation and are moving into analysis and risk characterization. Many of the teams are reconfiguring to ensure that adequate expertise is on the teams for the next phase. Some teams have obtained substantial grant and extramural funds to expand and improve the risk assessment based on the success of the first phases of the case study work. It is anticipated that an additional 2 years will be necessary to complete the full ecological risk assessment and finalize ecosystem-level guidance.

8.3.4. Examples of U.S. Department of Defense Activities in Ecological Assessments

Ecosystem management was adopted by the U.S. military in recognition of the U.S. Department of Defense's (DoD) responsibility as a manager of public trust resources that encompass 25 million acres. It also was recognized that responsible management with a long-term perspective will ensure the continuing availability of training resources, thereby enhancing the sustainability of the military's readiness mission. The Army's Integrated Training Area Management Program, implemented on more than 60 installations nationwide, is an excellent example of the military's efforts to integrate land management objectives with combat requirements through standard methods for monitoring land condition and trends, managing training lands to their carrying capacities, and rehabilitating resources toward a natural state of biodiversity. Within the Army Corps of Engineers Civil Works Program, which is responsible for managing an additional 12 million acres of Federal lands and waters, there is a long history of cumulative impact assessment of watersheds that is now helping to develop risk-based approaches in many regions.

An excellent handbook for military resource managers, *Conserving Biodiversity on Military Lands*, was recently published by DoD and the Nature Conservancy. In addition, the

Army published *Tri-Service Procedural Guidelines for Ecological Risk Assessment* in June 1996, which provides cost-effective tiered procedures with which to coordinate the defense ecological risk assessment efforts of contractors and follows the paradigm put forward in EPA's Framework for Ecological Risk Assessment (U.S. EPA, 1992).

8.3.4.1. *DoD's Ecosystem Management Policy*

Initial DoD guidance established the goal of ecosystem management to balance sustainable human activities, such as the support of DoD missions, with the maintenance and improvement of native biological diversity. Ecosystem management is a balance of ecology, economics, and social values. Partnering and public involvement are stipulated as means to achieving shared goals and making decisions. Goodman (1994) outlined 10 ecosystem management principles and guidelines, which can be summarized in four general themes: ecological approach, stakeholder involvement and collaboration, scientific and field-tested information, and adaptive management. This guidance was formalized in 1996 (DoD Instruction 4715.3, Environmental Conservation Program, May 3, 1996). The following examples illustrate how the military services and DoD are making strides toward full implementation of ecosystem management.

8.3.4.2. *Site Examples*

At Camp Pendleton, California, a project entitled Alternative Futures for the Region is to "examine the connections between urban, suburban, and rural development and the consequent stresses on native habitats and biodiversity." The study poses an important question: How will urban and suburban growth and change that is forecast and planned in the rapidly developing area between San Diego and Los Angeles influence biodiversity? The question is particularly relevant for Camp Pendleton because it constitutes the largest unbuilt segment of land on the southern California coastline and one of the most biologically diverse environments in the United States. Given its position and cache of unbuilt land, Camp Pendleton is central to maintaining the long-term biodiversity of the region. Camp Pendleton plays a key role in the connectivity of the region's ecosystems and over the long term faces the risk of becoming a "habitat island" for species. Camp Pendleton is also key to the military's readiness mission, being the only facility on the West Coast where amphibious assault maneuvers can be practiced. Camp Pendleton resource managers believe that a regional perspective is necessary if a true ecological perspective is to be achieved and that an ecological perspective enhances the long-term readiness mission. The project asks, "Can appropriate management of biodiversity and landscape planning allow the military to more effectively manage its property and efficiently fulfill its mission?" From the Camp Pendleton perspective it asks, "How might issues of biodiversity affect or influence land management activities of the camp?" and "How might future development or conservation 'upstream' from Camp Pendleton influence hydrology, ecosystems, and biodiversity on the base and thus potentially influence its primary mission of training?"

In the Chesapeake Bay Program (CBP), each Federal agency commits to managing the Chesapeake Bay watershed as a cohesive ecosystem and to working together and with EPA, States, and other parties to achieve the goals of the agreement. DoD is the lead agency in two key areas: (1) a commitment to upgrade all of its wastewater treatment plants and (2) inclusion of ecological value information in the decision-making process for the disposal of closed Federal facilities. In June 1994, the Navy was designated as the DoD lead in the CBP. Currently, 65 military installations are in the watershed, ranging from small radio transmitter facilities to large industrial and operational installations. The Navy is coordinating with Federal agencies on pollution prevention assessments and is coordinating with the other services to implement the DoD commitments to the agreement of Federal agencies on ecosystem management in the Chesapeake Bay.

At the Mojave Desert Ecosystem Initiative (MDEI), is a project led by the U.S. Army, peer-reviewed science is used to support land management decisions. The project goal is development and implementation of a database to facilitate collection, storage, transfer, sharing, and analysis of information regarding inventories, resource assessments, scientific documentation, and land management by all Federal, State, and local agencies and other interested parties. Ultimately, a queryable database will provide land managers and resource specialists with the tools for attempting to create a regional-scale database to affect dynamic, sustainable ecosystem management. MDEI is an important example of DoD's ecosystem management activities for several reasons: (1) It is an attempt to provide uniform data coverage across an entire scientifically defined ecoregion, regardless of political or administrative boundaries; (2) data collection, interpretation, documentation, and sharing will be a significant tool used for integrated planning and decision; (3) it provides an important model for sharing, integration, and use of data for ecosystem management purposes by a broad and varied group of participants; and (4) DoD's military trainers have been effectively integrated into the MDEI's program.

Adaptive management means the ability to change management structures and protocols to adjust to new or enhanced understandings advanced by the scientific community. Eglin Air Force Base, a 463,000-acre facility near Pensacola, FL, is home to the largest remaining longleaf pine system. Eglin and the surrounding landscape contain 153 rare species, including 13 that are federally listed, and many exceptional occurrences of imperiled natural communities. In partnership with the Nature Conservancy and 30 other organizations, Eglin has developed an ambitious ecosystem management program featuring an adaptive approach. Among the natural resource management program's most important goals is to restore and maintain the resiliency of native species and ecosystems. Eglin's military and natural resource management staff believe this approach best provides the broadest array of options for pursuing the base's military mission of testing conventional weapons and munitions. As it is being practiced at Eglin, adaptive management is an integrated, science-driven, and policy-based set of methods and principles for grappling with regional-scale environmental management problems. It seeks to answer two fundamental questions: (1) How do ecosystems change, and (2) how do institutions learn and adapt? Its goal is to integrate knowledge of ecosystem behavior with the policy processes of human institutions and to create learning institutions that can adapt to ecological and social change. With highly unique and high-value posts, camps, and stations, or "habitat islands" in the context of this report, DoD and the U.S. military services will continue to partner with neighboring ecosystem managers, experts, and the public to sustain our Nation's ecosystems for present and future generations.

8.4. RISK ASSESSMENT METHODOLOGY DEVELOPMENT

8.4.1. Expanded Use of the EPA Guidelines

Several agencies have gained experience with ecosystem assessments in recent years. These assessments have varied in scope, cost, and specificity of problems addressed. The agencies and scientists involved have learned lessons along the way, and there is general consensus that the utility of the assessments has improved as experience has been gained. Likewise, practitioners believe that individual assessments should be tailored to address the specific issues and circumstances generating the need for the particular assessment. However, as the need for ecosystem assessments appears likely to continue or expand, continuation of a completely "hand-crafted" approach is not efficient, will overuse available scientific resources, and will not sustain improvement in the assessment craft. We believe expanded use of the EPA Guidelines for Ecological Risk Assessment (U.S. EPA, 1998) offers an opportunity for several agencies to improve the efficiency and utility of ecosystem assessments. While the guidelines were developed for EPA use, judicious use by other agencies can provide government-wide benefits.

Ecosystem assessments do not focus on adverse impacts. In fact, their main focus is to provide comprehensive, integrated information to assist with planning and decision making in an ecosystem context. The EPA guidelines are designed to evaluate the likelihood of adverse effects because they are based on a risk assessment paradigm. The conceptual impasse between ecosystem assessments, which do not have an a priori focus on adverse impacts, and the EPA ecological risk assessment guidelines, which do have an a priori focus on adverse effects, is more apparent than real. Sustainability is the goal of ecosystem management, and the EPA guidelines specifically address methodologies for translating sustainability goals to risk assessment endpoints.

Dialog among parties interested in ecosystem assessment would benefit from an agreement on general long-term goals for ecosystem management, such as sustainability, and the translation of those goals to endpoints amenable to ecological risk assessment approaches. Scientists and/or risk assessors should be involved as facilitators of this dialog while avoiding a role as determiners of the goals and endpoints. Benefits for decision makers and other interested parties will be greater accuracy, clarity, and precision of scientific information available for decision making. Benefits for ecosystem assessment scientists and/or risk assessors are clarity of expectations and lessening of end product controversy.

Flexibility and rigor need to be balanced when use of the EPA guidelines is expanded for application to ecosystem assessment. Traditional risk assessments require data and process rules that are simply not available for most ecosystem assessments. The EPA guidelines clearly recognize the need to adjust risk assessment data rigor to the information available. The guidelines are sufficiently flexible for application to most ecosystem assessments. Principals responsible for ecosystem assessments need to embrace this flexibility while striving to retain as much rigor as possible. Expanded use of the EPA guidelines will increase the value of the Agency's investment in producing them while simultaneously increasing the value of ecosystem assessments that utilize them. Agencies responsible for ecosystem assessments and other ecosystem management activities should seek to understand the EPA guidelines and expand their use. EPA should actively seek to transfer guideline technologies to agencies with ecosystem management responsibilities and expand their use.

8.4.2. Technical and Research Challenges

Ecosystem management is a complex topic that contains a variety of challenges. Ecosystem management needs to be based on sound scientific studies and assessments. However, it also needs to reflect societal values and issues, political and economic concerns, and the decisions need to be legally defensible. Challenges include better linkages of research and technical information to the way society makes decisions in general and how ecosystem management is implemented in particular. Developing effective methods to communicate science and management options and consequences to the public, decision makers, and other stakeholders is a critical need. Successful partnerships between elected officials, the public, interested parties, and scientists have produced effective management programs for the Chesapeake Bay, south Florida, and other regional programs. The experiences gained from these partnerships need to be applied to other regional programs.

8.5. RISK ASSESSMENT IN ECOSYSTEM MANAGEMENT DECISION MAKING

Ecosystem management is the continuous process of holistically managing the physical, biological, and human components of ecosystems. The concepts underlying risk management are relatively straightforward (Marcot, 1986; Bartel et al., 1992; Burgman et al., 1993; Covello and Merkhofer, 1993; Morgan et al., 1990; Lackey, 1994; Suter, 1993). However, the joint application of the ecosystem and risk management concepts in a complex of ecological, organizational, and sociological processes is quite difficult.

8.5.1. The Risk Management Cycle and Ecosystem Management

Risk assessment is part of a cycle of processes that make up risk management. Ecological risk assessment is described in earlier sections of this document. Potential application of the risk management process to ecosystem management would involve eight phases:

1. **Hazard identification**—identifying human actions or natural events, the conditions under which they could potentially produce adverse effects, and the parts of the ecosystem that might be affected.

2. **Risk assessment**—characterizing risks imposed by some proposed action by estimating magnitudes of potential loss, exposure pathways, and likelihoods of occurrence.

3. **Evaluation**—judging the relative acceptability of assessed risks in light of policies, standards, organizational or cultural norms, public opinion, and other expressions of human values. Also, comparing different risks for their relative contribution to the overall level of severity.

4. **Adjustment**—choosing strategies for modifying, avoiding, accepting, or otherwise dealing with the risk profile of proposed actions or likely natural events. These choices involve comparing risk adjustment benefits and costs of various strategies and policy instruments and making difficult tradeoffs among risks and costs.

5. **Implementation**—interpreting the strategy mix in practical standards, guidelines, and incentive systems.

6. **Monitoring**—tracking the effectiveness of the risk adjustment strategies by measuring exposure pathways and risk endpoints sensing for "signal" events that could trigger adaptive responses.

7. **Adaptive Management**—strategies can be implemented through modifications in the proposed actions, mitigations for particular risks, or responses under a planned adaptive management program (Holling, 1978; Walters, 1986).

8. **Risk communication**—translating the results of one phase to another among ecosystem managers, scientists, policy makers, and the public. The traditional view of risk

communication was of a one-way flow of technical information from experts to the public. Recent approaches emphasize multiway communication with an emphasis on understanding the mental models and belief systems on which people judge the acceptability of risks. For the risk management cycle to work successfully, risk communication—clarity, completeness, accuracy, and compatibility with information processing styles—needs to be built into every phase of the cycle.

While these eight phases share some important similarities with the Ecological Risk Assessment Framework, as described earlier in this document, differences are illustrative of the gaps that currently exist between the framework and application of risk management in ecosystem management.

8.5.2. Risk Management and Decision Quality

The effectiveness of the cycle depends in part on the quality of the human judgments and decisions that support it. A high-quality decision is one that (1) solves the correct problem; (2) clearly describes the problem, criteria, and alternatives to the decision maker; (3) generates and evaluates many relevant alternatives; (4) makes choices consistent with criteria and information; and (5) provides for learning that will improve future decisions.

Most successful attempts to improve decision making have involved better organizing and structuring of basic cognitive tasks. Kleindorfer et al. (1993), Dawes (1988), Bazerman (1994), and other decision scientists contend that unstructured tasks are subject to many biases and illusions. Generic decision tasks include (1) process mapping, (2) problem framing, (3) intelligence gathering, (4) evaluation and choice, and (5) learning from feedback. Each of these tasks are subject to unique biases and opportunities for improvement.

Risk management involves decisions about how to reduce probabilities, lower potential losses, interrupt exposure pathways, or collect information to better predict events (MacCrimmon and Wehrung, 1986; Head and Horn, 1991). Each phase of the risk management cycle corresponds to one or more generic decision tasks. The cycle itself is a process map that lays out a sequence of steps and prescribes methodologies and protocols. Hazard identification is a problem-framing and intelligence-gathering task. Risk assessment takes these tasks to higher levels of rigor by requiring probabilistic judgments and analysis of complex pathways. Risk evaluation and adjustment are tradeoff evaluation and choice tasks. Risk monitoring is an intelligence-gathering and learning task.

8.5.3. Risk Assessment as a Decision Aid

As a decision-aiding tool, risk assessment can be judged by six criteria (Covello and Merkhofer, 1993): (1) logical soundness, (2) completeness, (3) accuracy, (4) acceptability, (5) practicality, and (6) effectiveness. The first three criteria are measures of scientific discipline; the last three relate to the users of the assessments' outputs.

Logical soundness is the degree to which the assessment conforms with fundamental theoretical assumptions of basic science, the specific field, and the laws of probability. Completeness refers to whether the assessment accounts for all considerations and scenarios that are relevant to a reasonable choice of policies. Accuracy is whether the assessment correctly describes sources of uncertainty, the probability of their events, and their effects. Sources of inaccuracy include biases and errors in data collection, model specification, and expert judgment, as well as inappropriate application of modeling methods. Inaccuracies can be minimized by sensitivity testing, peer review, and comparison with other assessments or empirical patterns. Acceptability is whether decision makers understand the assessment and find it believable. Barriers to acceptability include lack of public credibility of risk experts, experts' limited understanding of public risk perceptions, and failures to disclose limitations and uncertainties. Credibility problems stem from instability of results under different assumptions and data, complexity of outputs, overuse of technical jargon, invasion of assessment results with advocacy for a risk adjustment option, and lack of trust for the agency doing the assessment. One ironic barrier to acceptability is how uncertainty is displayed. Because humans prefer certainty in answers and predictions, even if they are illusory, risk assessments that describe large degrees of uncertainty tend to be rejected. When risk assessors are most candid about environmental uncertainties, the risk manager or public is likely to be most disappointed because the assessors cannot be definite. If risk assessors ignore or obscure uncertainties and gives unambiguous predictions and advice, their credibility is damaged, especially if the risky event actually occurs (Carpenter, 1993). Practicality relates to whether the assessment can be employed in a real-world environment with deadlines and limited resources and information. Risk assessments usually require interdisciplinary teams, iterations, and many interlocking steps. Risk assessments, especially large-scale assessments, need to be well managed; scientists who serve on assessment teams do not have the inclination or abilities to manage product-driven efforts. Too many risk assessments evolve into piecemeal research projects, with individual scientists pursuing their own subjects and then trying to assemble what they have as the deadline nears.

The effectiveness of a risk assessment is ultimately how much it improves the risk adjustment decision making in the ecosystem management organization. A risk assessment does not stand alone as an estimate, an analysis, or a report, but is actually part of a way of thinking. Using probabilistic information in making decisions is not easy or natural for most human beings.

Most people focus disproportionately on magnitudes of dire outcomes, almost ignoring probability information. People have many automatic or routine ways of dealing with risk that can substitute for analyzing risks. Such behaviors include delaying the decision, delegating or otherwise transferring the risk, ignoring uncertainties, treating uncertainties as if they were certain, collecting information, modifying the management alternatives, buying insurance, making contingency plans, and setting performance standards. If followed without any knowledge of the nature or the degree of the risk being managed, these strategies can misallocate intellectual, financial, and physical resources.

Many still approach risk assessment as a way of justifying and documenting decisions that are already made. To these persons, a good risk assessment will be disappointing because it will expose many incorrect and unfounded assumptions.

8.5.4. Expert Judgment in Risk Management

Quality in professional, or so-called "expert," judgment is an important element of decision quality, especially when there are no precedent events or data, and statistical evaluation is not possible. In these situations, assessment quality may be gauged more on how the judgment mobilizes knowledge, both theoretical and practical, to estimate effects and how the process advances and contributes to the decision process.

Expert judgments of ecological structure and stressor responses enter into the specification of measurement endpoints and the estimation of likelihoods and severities. Judgments of acceptability of risks enter into the risk evaluation phase; judgments of managerial feasibility are the basis for selecting risk adjustment actions. Quality judgments rationally use scientific and other sources of information and are expressed in ways that can be understood and used by decision makers and stakeholders.

Quality expert judgments are important sources of information in risk assessment and risk adjustment. Risk assessment is a form of judgmental hypothesis testing. The null hypothesis is that there is no risk; alternative hypotheses are that the risk may be at various levels. If the risk assessor judges that there is a risk, efforts may be made to adjust it. If the event that creates the loss never actually occurs, the risk management process has made a false-positive error and incurred unnecessary costs. If the expert judges that there is no risk and the event actually occurs, there has been a false-negative error with losses that are perhaps unacceptably high. A good risk management program will attempt to minimize the combination of false positives and false negatives. The symmetry of the loss and cost distributions should guide the level of effort put into assessment and adjustment strategies. Where false-negative losses overwhelm false-positive costs, it is better to invest in more sophisticated assessment processes and more stringent risk adjustments.

Three types of bias influence expert judgments. Task bias is caused by the improper definitions of events or initiating conditions leading the assessor astray. Conceptual biases include motivational biases (wishful thinking or advocacy) and cognitive biases (systematic patterns of thinking that do not allow full expression of subject matter knowledge in probability form). Expert judgments can be improved by structuring elicitation processes to keep judgments relatively free of these biases and to fully reflect the knowledge of the experts. Process guidelines include avoiding experts who have agendas or preconceived notions, obtaining estimates from several sources, challenging experts to explain their rationale, encouraging experts to move estimates from their initial estimate "anchors," requiring experts to provide degrees of uncertainty, checking estimates against any records of similar losses, and removing sources of distraction and motivational bias from the elicitation environment (Cleaves, 1994).

8.5.5. Risk Evaluation, Adjustment, and Decision Quality

The risk manager should fully evaluate a range of options for managing risks, including incentive-based and other flexible policies for allowing managers to assess and adjust risk according to site-specific information, experience, and knowledge. Risk policy is composed of rules and standards and other instruments that signal which risks are most important and what levels of those risks are acceptable. Protection standards are written to ensure particular behaviors of human managers toward ecosystem components. Standards limit improper outside factors from influencing resource management decisions. Standards convert probabilistic choice into a deterministic rule (Keeney, 1983). Whoever develops standards makes critical tradeoffs: those who accept or implement standards may not have the same degree of discretion. Some flexibility is beneficial for sites at smaller scales of analysis and choice. Standards that attempt to minimize magnitude discourage managers from basing their decisions on the relationship of magnitude and probability. Standards that consider probability as well as magnitude may provide a useful tool for risk managers.

8.5.6. Risk Communication and Decision Quality

Implementing risk management in an ecosystem management context depends on clear communication among participants in the risk management cycle and on public support. The public will not accept risk assessments or management policies just because they represent expert judgment. Underlying psychological attributes of risk perception influence risk information. These attributes include (1) voluntariness or controllability, (2) dread or vividness, (3) familiarity with the outcome, (4) extent (degree of catastrophe) in the losses, and (5) future generational impacts (Covello et al., 1986; Sandman, 1985; Slovic, 1987; Cross, 1994). People focus on these attributes to adjust their judgments of magnitude, frequency, and degree of exposure. Some events have a high "signal" value in that they may symbolize the potential of more serious risks in the future.

Involving the public in risk management is the best way to better understand and work with risk perceptions. Many techniques such as focus group interviewing, group facilitation, and alternative dispute resolution can be applied to public involvement in risk assessment. Part of this effort should be devoted to helping the public recognize and contribute to decision quality. All parties should be able to ask questions about decision quality: What perspectives are involved? What factors have been omitted? Are major uncertainties quantified and explained? Have sensitivity analyses been conducted? How are the risk assessment and risk adjustment tasks separated to minimize bias? An informed public will appreciate honest efforts to characterize risks, be more creative in suggesting risk policies, and be less inclined to reject assessment results.

8.6. NEXT STEPS

This chapter has provided some examples of ecosystem assessments for ecosystem management, views of how risk assessment methodologies could contribute to more efficient ecosystem assessments, and a description of how improved ecosystem management decision making would be the result of hybridizing ecological risk and ecosystem assessments. The following "next steps" would help natural resource agencies move along that pathway.

- Link ecological risk assessment and ecosystem management to improve organizational and analytical consistency in support of multiple scales of resource management.

- Expand the use of EPA's Guidelines for Ecological Risk Assessments (U.S. EPA, 1998) across agencies to improve the efficiency and utility of ecosystem assessments.

- Improve valuation technology to provide better definition of societal values and preferences and to better achieve awareness and active involvement of a diverse array of stakeholders.

- Link ecosystem assessments using common information themes and protocols that provide analyses of ecosystem process, structure, and function at multiple temporal and spatial scales.

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