ECOLOGICAL STEWARDSHIP

A Common Reference for Ecosystem Management

Volume III

- Public expectations, values, and law
- Social and cultural dimensions
- Economic dimensions
- Information and data management

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Assessments for Ecological Stewardship

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Key questions addressed in this chapter

- *Comprehensive management is crucial for successful completion of ecological assessments*
- *Assessment processes need to be tailored to accommodate the time, funds, and people available*
- *The most important step in assessments is to define issues that can guide the assessment*
- *Prior to data collection, complete assessment design and contracts between assessment teams and management*
- *Linking assessments to monitoring is key in most adaptive management models*

Keywords: Resource conditions, assessments, scale, Southern Appalachian Assessment, Interior Columbia River Basin Assessment

1 INTRODUCTION

Depending on the agency, discipline, or audience, assessments supply data and information to address relevant policy questions and to help make decisions (Streets 1989, Thorton et al. 1994). Data collected in assessments estimate, measure, appraise, rate, characterize, or describe various resource conditions. If properly executed, assessment processes can draw conclusions and make recommendations on how to manage natural resources (Deuel and D'Aloia 1995). Assessments range from those required by the Resources Planning Act (national), to describing stand conditions (site) prior to applying treatments (Forest and Rangeland Renewable Resources Planning Act 1974, Daniel et al. 1979). Assessments have always been an integral part of natural resource management.

The rationale for conducting assessments varies. Some assessments are directed by law or regulation while others answer a specific research question (National Environmental Policy Act 1969, National Research Council 1990). Addressing issues or concerns about land use is a common reason for completing an ecological assessment (Zonneveld 1988). Changes in ecological conditions also indicate need for an assessment (Noss and Cooperrider 1994). The latter two reasons are in particular, fundamental to most adaptive management models used in managing natural resources (Holling 1978, McGinty 1995).

2 ADAPTIVE MANAGEMENT

Adaptive management models for ecosystem management usually contain a minimum of four components: monitoring, assessments, decisions, and implementation (Holling 1978, McGinty 1995, Haynes et al. 1996) (Fig. 1). Most models are iterative and can begin with any component. For example, ecosystem changes disclosed by monitoring may trigger an assessment, or budget priorities may alter decisions and implementation strategies. Issues, concerns, or questions external to the planning model can initiate the process, such as a new law, regulation, or a new issue. For example, Congress initiated the Sierra Nevada Ecosystem Project (SNEP Summary 1996) to address old-growth issues in California. Likewise, the Interior Columbia River Basin project (ICRB) was partially triggered by Presidential action to address forest health issues in eastern Oregon and Washington (Quigley et al.1996). Because humans are a component of ecosystems, an essential part of the model is participation and collaboration of all interested and affected parties in all components. These stakeholders, and especially those affected by resource management, need to be committed to finding a solution (Salwasser 1995).

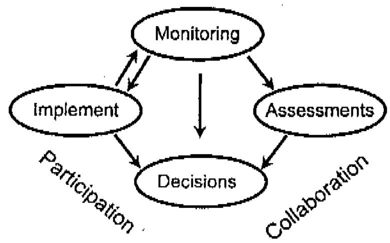

Fig. 1. The four components of most adaptive management models. Participation and collaboration among stakeholders, interested individuals, and agencies are important elements of an adaptive management model.

3 ECOSYSTEMS

An ecosystem, which is a human construct, can be defined as: "communities of organisms working together with their environments as integrated units. They are places where all plants, animals, soils, waters, climate, people, and processes of life interact as a whole. These ecosystems/places may be small, such as a rotting log, or large, such as a continent or the biosphere. The smaller ecosystems are subsets of the larger ecosystems; that is, a pond is a subset of a watershed, which is a subset of a landscape, and so forth. All ecosystems have flows of things — organisms, energy, water, air, nutrients — moving among them. And all ecosystems change over space and time (Thomas 1956, Burgess and Sharpe 1981, Shugart 1984, Waring and Schlesinger 1985, Botkin 1990, Kimmins 1992). Therefore, it is not possible to draw a line around an ecosystem and mandate that it stay the same or stay in place for all time" (Salwasser et al. 1993).

Managing ecosystems means manipulating and understanding their processes, and their structural, and functional components. These components are evaluated during the assessment process. Structures are the patterns of association (vertical, horizontal, or temporal) among ecosystem elements. For example, structures might include plant species composition, forest fragmentation, or road density. Processes are the actions that link organisms (including humans) and their environment (Lindeman 1942, Aber and Melillo 1991, Noss and Cooperrider 1994). Examples include successional development, nutrient cycling, carbon sequestration, decomposition, and photosynthesis. Functions are the specific role or activity of an ecosystem element. For example, fire functions as a rapid decomposer of organic material and erosion moves soil surface materials (Hunt 1972, Agee 1993, Sala and Rubio 1994).

Ecosystems and their processes, structures, and functions are all defined by the observer (Rosen 1975, Pattee 1978), who needs to understand several principles on ecosystems' organization and how they interact with each other. These principles include understanding that ecosystems change over time, can be viewed as having multiple organizational levels, have economic, social, and biophysical limits, and have limited predictably.

3.1 Ecosystems Are Dynamic

Ecosystems change and develop along many pathways (O'Neill et al. 1986, Urban et al. 1987). They are the products of their history (Barret et al. 1991). They can be stable in the sense that when disturbed they tend to return to some constant state, or they can be cyclic such that the steady state is always changing within some definable bounds. Fires, volcanic eruptions, floods, and wind events along with people setting fires, clearing land, and introducing new (exotic) species are sources of ecosystem disturbance (Agee 1994, Robbins and Wolf 1994). Within limits, forest and grassland ecosystems are generally resilient to a variety of disturbances (Hilborn and Walters 1992). Past management decisions, combined with natural environmental disturbances and conditions, limit future management options (O'Laughlin et al. 1993, Maser 1994). And just as past disturbances and actions of past human generations shaped the ecosystems of today, actions of this generation will define ecosystems of the future.

3.2 Ecosystems Can Be Viewed Hierarchically

Defining ecosystems with multiple organizational levels varying over time and space is useful. These levels can be organized within a hierarchy, in which every level has discrete ecological functions but at the same time is part of a larger whole (Koestler 1967, Allen and Starr 1982, Allen et al. 1984,). Higher levels usually occupy larger areas and are usually characterized by longer time frames (Delcourt and Delcourt 1988, King et al. 1990).

In landscape ecology, hierarchy theory allows for the definition of ecosystems and the linkages between the different levels of ecological organization. In a vegetation hierarchy, trees are nested within forests, forests nested within series, and series nested within formations. Many environmental constraints, vegetative patterns, human behavior, and disturbance processes can be described for each level, time frame, and area (Pickett et al. 1989, Robbins and Wolf 1994). Spatial extent can range from a few square meters to hundreds of kilometers, and time frames can range from less than a year to thousands or millions of years.

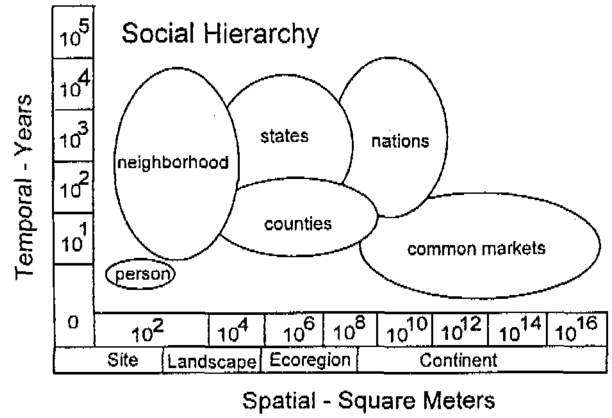

Fig. 2. We can view ecosystems as having multiple spatial and temporal scales nested within each other. Each organization level (*for example counties*) *occupies its own spatial extent and is* characterized by specific periods (Haynes et al. 1996).

Human hierarchies may also be defined temporally and spatially (Fig. 2). Societies can be described along organizational or institutional continua (Haynes et al. 1996). However, organizational levels, time frames, and spatial extents that are significant to human decision making often do not correspond to the same time and spatial hierarchies of biophysical systems. For example, ecosystem processes (such as soil formation) that occur over long time frames (centuries or millennia) hold little meaning for political processes that operate biennially. In addition, because people respond to environments symbolically, places cannot usually be defined using biophysical hierarchies. Moreover, some economic processes operate simultaneously across multiple levels.

3.3 Ecosystems Have Limits

In all ecosystems, limits to the production and accumulation of biomass (plant, animal, and human), depend on the developmental pathway an ecosystem follows (McCune and Allen 1985, Kay 1991). In addition, the environment is constantly in flux, causing ecosystems to change. Humans must recognize that, therefore the capability of an ecosystem to provide goods and services also has its limitations. Unfortunately, people often make demands that exceed an ecosystem's biological or physical capabilities (Robbins 1982, Young and Sparks, 1985). An example of such demands is the decline in the world's major fish stocks (Hilborn and Walters 1992).

3.4 Ecosystems Have Limited Predictability

The events that influence ecosystem patterns and processes have limited predictability (Holling 1986).

Predictability varies over temporal, spatial, and social organizational levels (Bourgeron and Jensen 1994). For example, from year-to-year, wildfire occurrences are anticipated based on time of year and environmental conditions, but the specific intensity, size, and location of fires are less predictable. Similarly, eruptions of Cascade volcanoes have occurred, on average, twice each century for the past 4,000 years (Dzurisin et al. 1994). However, when the eruption will occur, its size and effects cannot be predicted. A social example is the ability to predict crime rates at the regional or community level, but speculating the occurrence of a crime at a particular household is much more difficult.

Although our knowledge about ecosystems is far from complete, understanding that ecosystems are dynamic, limited, and unpredictable are important when conducting assessments. Often natural resource assessments address only one resource such as wood product potential or a single wildlife species. But considering all components within an ecosystem should help managers better grasp and better predict the impacts of natural and human caused events.

4 ASSESSMENT MANAGEMENT

Assessments, especially large ones, can be easily influenced by internal and external forces. Strong management is necessary to prevent these forces from compromising the assessment. National to local special interest and political entities can control budgets and the availability of information. Likewise, forces within agencies can change budget and people priorities. Attaching it to a specific decision document (Environmental Impact Assessment, EIS) can direct the assessment to provide information for only that decision. An assessment of this type would not likely characterize ecosystems fully and would not draw independent conclusions. Assessment team members can also have priorities and desires. Singly or in combination, such factors can disrupt, delay, misdirect, or complicate assessments, and they are often overlooked and difficult to handle.

The Southern Appalachian (SAA) (SAMAB Report 1 1996) and the Sierra Nevada (SNEP Volume 1 1996) assessments appeared to adhere relatively well to the time constraints and budgets. In particular SAA had a strong management team that insulated the assessment team from most conflicts. In addition, they developed a strong contract (study plan) between the management team and the individual assessment teams that was strictly enforced, keeping the process focused. In contrast, management could not insulate the assessment teams from the many external factors that bombarded the ICRB. Because of the changing geographical extent, changing assessment questions, and the constant pressure of providing information for two large and politically volatile EISs, study plans were constantly being adjusted and modified, which affected time-lines and budgets. Managers need to control assessments so they meet objectives, budgets, and time constraints. One way to do this is to concentrate on the assessment design.

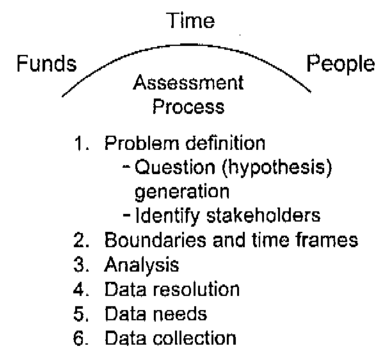

Fig. 3. Overall assessment design. Funds, time, and people available are the primary controlling factors.

5 ASSESSMENT DESIGN

Completing a design prior to collecting data is the most efficient and logical way of conducting assessments. Design includes problem definition, boundaries, scales, analysis procedures, and determining data resolution and needs (Fig. 3).

5.1 Problem Definition

The most important step in the assessment process is to define the assessment problems or questions that address resource management issues. This step can begin with the collection of information through public, agency, interagency forums, and other methods. This information can be used to identify issues the assessment needs to address. For example: What are the important attitudes and values residents hold toward natural resources? Is timber quantity declining? Are old-growth forests rare? Is water quality declining? Who are the stakeholders? Is sightseeing the most common form of recreation in the National Forest?

Addressing such questions clarifies the values society places on natural resources. Recognizing the values comes through the participation of tribal, federal, state, local, and public entities. Because ecosystems seldom conform to jurisdictional boundaries, the participation of these stakeholders is essential.

Among the stakeholders, Native American tribes have a sovereign status recognized through treaties and executive orders. Each tribe is a separate entity, and relationships need to be established with each tribe. Tribal governments vary in format among tribes. Face-to-face meetings between the decision makers of the agencies and the tribes are essential.

Public participation helps agencies understand people's values and helps the public understand the agencies' objectives, methods, data sources, and assumptions. Participation by all parties should promote increased understanding and improve cooperation and trust. This cooperation and trust can be one of the significant results of the assessment process, which was the case for the Southern Appalachian Assessment (SAA) (SAMAB Report 1 1996).

Information needs to be gathered to ensure that the issues are well defined and the concerns of stakeholders are recognized. Emotions (job losses), traditions (hunting), resource changes (fire frequency), and values (commodity vs. preservation), for example, all define an issue. The primary issue for the SAA was to identify any potentially serious problems before they threaten the well being of the region's natural resources (SAMAB Report 1 1996). In some circumstances, policy makers in the absence of assessment management may provide an issue that masks the real issue. For example, policy makers might define the loss of the habitat for an endangered wildlife species, as an issue but the real issue is the amount and location of big, old trees and their harvesting (spotted owl vs. old-growth). Under these circumstances tremendous pressure is placed on management to provide an assessment for a poorly defined issue.

The issues and accompanying background information are used to define specific assessment questions or problems. Ideally problems should be stated as a testable hypothesis (Salwasser 1995). This might not be possible in all cases, but precise questions that address issues will define the past, present, and future structures, processes, and functions of ecosystems to be assessed. Questions determine how the ecosystems will be defined and what the components are. Questions that address well defined issues set the goals for the remainder of the assessment process.

The New Hampshire Assessment (NHA) (1995) used a combination of questions and hypotheses to guide the assessment while SAA only used questions (SAMAB Report 1 1996). The SAA management team assigned each discipline of the science team a set of questions from which they developed an assessment plan. For example, the analysis of communities and human influences of the SAA was structured around seven questions (such as: How might management of natural resources impact the economic and social status of local communities in the region?), and the terrestrial assessment addressed four questions (such as: What are the status and trends, spatial distributions of populations and habitats in the SAA for federally listed threatened and endangered species?).

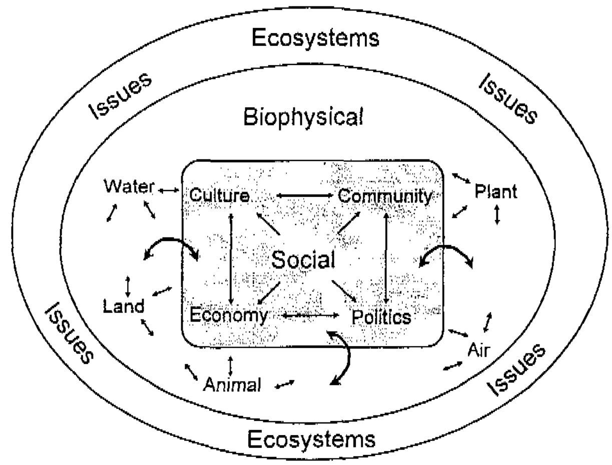

Fig. 4. Ecosystems comprise social and biophysical components (Haynes et al. 1996), with information, energy, organisms, etc., flowing (as indicated by the arrows) among and within the components.

Ecosystems are places where a multitude of biophysical and social components interact as a whole (Fig. 4). They contain complex flows of energy, organisms, water, information, capital, etc. within and among the social and biophysical components. Because of this complexity, assessment teams tend to gather large amounts of data describing ecosystems in great detail, but the information does not always address relevant questions. Well-designed questions can focus the researchers and limit the ecosystem components and interactions evaluated in the assessment to those that address the issues. For example, the SAA social/cultural economic team focused on population, migration, timber land area, income, social patterns, attitudes toward resource management, recreation settings, and sense of place (SAMAB Report 4 1996).

5.2 Boundaries

Delineation of assessment and ecosystem boundaries should be based on the questions, agency needs, and the biophysical, economic, and social attributes of the areas of concern (Lackey 1996, Clark et al. in press). Ecosystem boundaries should strive to encompass similar: biophysical patterns and processes (for example, existing vegetation, potential vegetation, regional climate, geology, and landform), hydrologic and aquatic processes (for example, river basin and watershed boundaries), and social settings (for example, land-use patterns). But boundaries used in assessments are highly individual depending on the questions, agencies, and political necessity. For example, for the Interior Columbia River Basin (ICRB) assessment a combination of state boundaries, river basin boundaries, and international boundaries was used to define the assessment area. This combination led the ICRB assessment to include portions of eastern Oregon and Washington, the state of Idaho and a portion of western Montana, but it excluded a large amount of the Columbia River Basin in Canada (Quigley et al. 1996). Similar criteria using a combination of biophysical, political, and administrative attributes defined the Southern Appalachian Assessment boundaries extending from Virginia to northeastern Alabama (SAMAB Report 1 1996). The Sierra Nevada Ecosystem Project (SNEP Volume 1 1996) used similar criteria for establishing its boundaries. In contrast, the New Hampshire assessment (1995) relied heavily on state boundaries for delineating its assessment.

5.3 Spatial Scales

The choice of the assessment geographic scales depends on the questions and the selected ecosystem components. Geographic scales can range from the regional and subregional areas to the smaller landscape and site specific areas. It is highly desirable for assessments to include multiple spatial scales because it may be difficult to adequately address regional ecosystem patterns and processes that are only apparent at landscape or smaller spatial scales. For example, SAA (SAMAB Report 5 1996) used three spatial scales to address the distributions of habitats and populations of threatened and endangered species (Table 1). The largest geographic area used included the entire Southern Appalachians, while individual counties were the smallest.

Regional to continental spatial scales are the appropriate size to describe general trends and rates of change in resource conditions. At these scales we can describe broad-based conditions of biophysical, economic, and social ecosystem components (Fig. 5). For example, these large spatial scales can disclose regional trends in human populations and urban versus rural economic growth. The SAA, SNEP, and ICRB all did credible jobs in assessing large geographic areas and describing general trends and conditions.

Regional to continental spatial scales can provide information on the patterns of resources (for example, species distributions) and associated risks to resource values (for example, fire and insect hazard) that may not be apparent when assessing smaller areas. Ecosystem processes such as air pollution, climate, and industrialization are not always recognizable using small geographic areas. For example, the SAA devoted a large part of its assessment to addressing atmospheric questions (SAMAB Report 3 1996) that could not be described using small geographic areas. Most import-

Table 1. An example of using questions for determining the spatial scales used in an assessment adapted from Southern Appalachian Assessment (SAA) (SAMAB Report 5 1996). Issues or questions to be addressed: What are the status, trends, and spatial distribution of populations and habitats in Southern Appalachia for federal threatened and endangered species?

Ecosystem Component	Spatial Scale		
	Counties	Ecological Units	Total SAA
Forest cover type	X	X	
Rare communities			X
Threatened or endangered species	X	X	X
Species with viability concern	X	X	X
Major game species	X		X
Habitat suitability			X

Fig. 5. Continental spatial scales address general trends and rates of change in resource condition. Data collected at these scales have low resolution, but provide context for national and regional information and decisions.

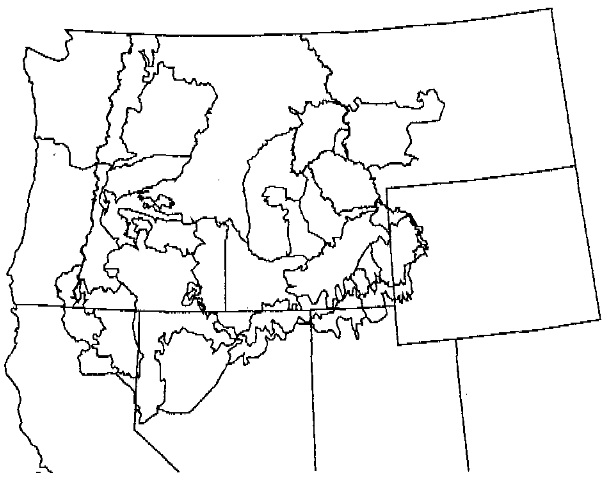

Fig. 6. Assessments conducted at regional and subregional spatial scales provide more specific information than continental spatial scales. For example, mid-resolution data collected at this scale might include patterns of vegetation composition, human population demographics, and strongholds of anadromous fish populations.

ant, these larger spatial areas provide context for problems, issues, and information developed for smaller spatial areas (Fig. 6).

Biophysical, social, economic, and political rationale can be used for defining subregional units. In the Interior Columbia River Basin (ICRB) the entire assessment area was divided into 12 smaller ecosystem delineations based basically on biophysical attributes (Quigley et al. 1996). Similarly, the New Hampshire assessment (1995) area was divided into nine ecoregions, which were further divided into landscapes. In some cases, questions are not easily addressed using biophysical attributes as the primary attribute for determining boundaries. Counties and state boundaries are often the preferred delineation, which was the case in the SAA and in the ICRB assessments for some of the social and economic attributes (SAMAB Report 1 1996, Quigley et al. 1996).

Smaller spatial areas can provide more specific information on items such as vegetation patterns or species composition that are not readily recognized using larger geographic areas. The SNEP assessment displayed the distribution of plant communities for subregions of its assessment area (SNEP Volume 1 1996). Similarly, smaller geographic areas can show trends in social well-being for communities of interest stratified by counties or groups of counties that would be impracticable and probably nonsensical for larger spatial areas. For example, in the SAA current and future human impacts were demonstrated using counties as the geographic unit (SAMAB Report 4 1996). By applying various scales, characterizations of large geographic areas provide context for ecosystem processes, structures, and functions that can only be characterized using these smaller areas.

Landscape to site-specific spatial scales provide the greatest detail (Fig. 7). This geographic extent may cover landscapes, watersheds, or individual project sites and specific human communities. To address questions at this scale, the New Hampshire assessment (1995) used landscapes and the SAA used counties. This geographic extent typically relied on detailed information regarding vegetation patches, stands, meadows, streams, and social and economic data. These characterizations can describe processes, structures, and functions such as nutrient cycling, nitrification, individual communities, and existing land uses that are not readily observed when assessing larger geographic areas. The processes, structures, and functions observed using these smaller geographic areas can be set in context using the characterizations of the larger geographic areas.

Use of multiple geographic scales also requires using different temporal scales that can range from hours to centuries. As with spatial scales some biophysical components may not be recognizable using short time frames (for example, soil formation), while others can only be recognized using small time increments (for example, soil heating by fire). The Sierra Nevada Ecosystem Project projected population density from 1990 to 2040 and evaluated lumber and wood product jobs for 20 years into the future (SNEP Volume 1 1996). The SAA projected European gypsy moth spread through 2020 (SAMAB Report 1 1996). By describing ecosystems using multiple time frames, the

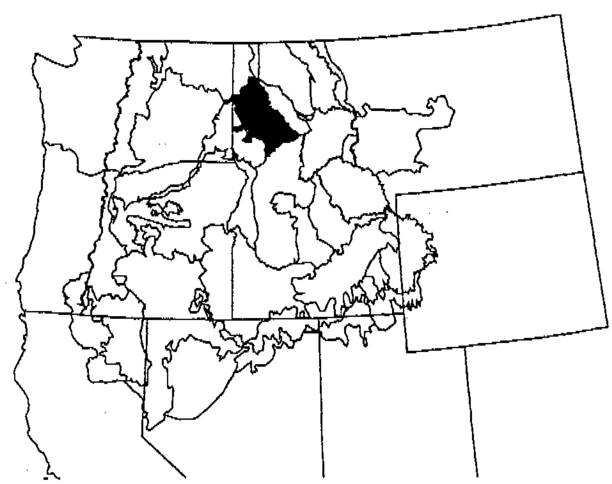

Fig. 7. Landscape to site-specific spatial scales provide the most detailed information. This mid to fine resolution information might include vegetation patches, stand locations, stream reaches, family incomes, and job classifications. This information is commonly used for local and sub-regional planning.

Table 2. Relations among assessment geographic scales and units commonly used to characterize ecosystems.

Geographic scales	Terrestrial units	Aquatic units	Social units
Global	Domain	Zoogeographic region	Continent
Continental	Division	Zoogeographic subregion	Nation
Regional	Province	River Basin	State
Subregion	Section/Subsection	Subbasin	Community
Landscape	Landtype association	Watershed/Sub-watershed	Community
Land Unit	Landtype	Valley section/ Stream reach	Neighborhood
Site	Ecological site	Channel unit	Individual

Table 3. Relations among assessments, issues, and planning as typically used by the U.S. Forest Service.

Typical Issues	Geographic Scale	Primary Organization Responsibilities
National (Resource Planning Act 1974)		
Neo-tropical birds Climate change National timber supply	Continental	National organizations
Regional Guides		
Widely distributed species (salmon, grizzly bear)	Regional	Multi-regional agencies
Roadless area		
Old growth Fire management	Subregional	Regional organizations Multiple national forests Combination of federal and state agencies
Forest Plans		
Timber volumes Vegetation patterns Specific fire management plans	Landscape	Districts Combinations of counties and municipal units
Area Plans		
	Land unit	District
Soil compaction Stand structures		
Project Plans		
Tree establishment Nest areas	Site	District

longer periods can provide context for components using shorter time frames, similar to describing ecosystems using multiple spatial scales.

The choices of spatial and temporal scales and the units used for an assessment are a compromise among the disciplines involved (economics to landscape ecology). For example, spatial and temporal scales commonly used to describe biophysical components do not necessarily conform to the temporal and spatial scales used to describe economic and social components. Often biophysical components are best described using watershed boundaries, while counties are the basic unit for describing social and economic attributes. At the larger geographic scales, terrestrial assessments tend to use domains as their units, while social assessments use continents. At the regional and subregional scales, provinces and sections are often used in terrestrial assessments, and social assessments tend to use communities (Table 2).

Using various spatial and temporal scales also results in information for planning and decision making at various levels within organizations. Continental and regional scale assessments provide information for national level planning such as those required by the Resources Planning Act (1974). Section and subsection ecological units as described by the National Hierarchy of Ecological Units (1993) are often found in regional and subregional assessments and address planning at regional and multiforest planning levels (Tables 2 and 3).

Ecological assessments need also to characterize rare or unique components of ecosystems. These can range from rare communities such as cobble bars, swamp forest-bog complexes, or karst lands that were described in the SAA, to locating ecologically significant areas in the Sierra Mountains (SAMAB Report 1 1996, SNEP Volume 1 1996). Nature Conservancy, federal lists of rare or endangered species, or other sources are starting points to identify these rare elements.

5.4 Indicator Variables

Indicator variables should be chosen to adequately describe the ecosystem condition (Hirvonen 1992, Landres 1992). In assessments they are used to describe the current, past, and future trends of ecosystems. For example, the Southern Appalachian Assessment (SAA) used tree sensitivity to ozone as a variable to predict impacts of ozone to Southern Appalachian forests. Using past research, they identified areas where ozone pollution may cause detrimental effects to vegetation (Jackson 1996).

Indicator variables can be used to detect ecosystem changes. For example, quantifying changes in forest composition can indicate changes in forest biodiversity, wildlife habitat, or disturbance regimes. The ICRB assessment used changes in species composition in dry forest types to indicate changes in fire regimes (Quigley et al. 1996). They noted that lack of fire in dry forest tended to change species composition from primarily ponderosa pine (*Pinus ponderosa*) forests to mixed confer forests.

Indicator variables are also communication tools (Hirvonen 1992). For example, number of chocolate chips, cookie size, and texture are all indicators of cookie taste —variables manufactures use to convey taste information to consumers. A similar approach is necessary in ecological assessments. Indicator variables need to communicate relevant information (fire risk, species loss, jobs loss) about the status of the ecosystem. Therefore, indicator variables should be chosen and defined with care because their definition takes time, people, and money (Hirvonen 1992, Landres 1992). It is imperative that they are used to address questions at the appropriate spatial and temporal scale.

Indicator variables and objectives should be stated concisely, in an understandable format, ideally in one concise sentence. This sentence can help avoid deviation from pursuit of preset goals. Although SAA authors did not define indicator variable with one sentence, they did have concise questions that the variables addressed (SAMAB Reports 1 through 5 1996). If the indicator variable is to determine detrimental effects, then the variable should have thresholds identified. The SAA did set sensitivity levels in their indicator variables to evaluate potential negative effects from ozone pollution (Jackson 1996).

If indicator variables are used to determine cause and effect, a controlled experiment is required that adheres to the assumptions of randomness and treatments to experimental units. In natural resource assessments, this statistical rigor can seldom be achieved. Therefore, indicator variables used in assessments should not try to describe cause and effect but rather differences, trends, or changes. In large assessments such as ICRB, SAA, SNEP, the results usually describe trends rather than cause and effect.

Indicator variables used to describe ecosystems should adhere to sound sampling protocols and be drawn from appropriately sized areas or populations (Mouat et al. 1992). These protocols should include the scale at which the indicator variable is being used, the sampling frame, suggested method of sampling, and the optimal time to collect data. This ensures that inferences can be described and detected differences, relationships, changes, or trends will be credible.

The use of indicator variables in assessments is experimental, and future knowledge may change how they are used. They do not provide a complete description of an ecosystem, necessitating flexibility in their use. Indicator variables can be used and applied inconsistently. Interpreted results from a selected indicator variable in one assessment may not necessarily be applied to another.

5.5 Data Analysis

Good data analysis depends on the preceding steps in the assessment design being handled correctly, beginning with problem definitions through variable selection. Data analysis techniques will further define the scope and intensity of data needed, resulting in increased assessment efficiency, decreased costs and valuable time used wisely. Analysis techniques include statistical procedures such as T-tests, frag-stats, ANOVA, and discriminate functions. Models, scenarios, or rating an ecosystem to determine its integrity or resiliency are other techniques.

An ideal assessment would consist of information integrated from the inception by addressing integrated questions. However, although most resource information is collected by individual disciplines addressing separate questions, through coordination, data of mutual interest can be shared. For example, assessments often use watersheds as the basic sample units. The biophysical environment described in these watersheds can be used to describe potential habitats of wildlife and plant species.

5.5.1 Scenarios

Depending on the issues, scenario planning provides a valuable approach to describing possible futures. This iterative series of "what if?" questions explores the degree of difference among a wide spectrum of goals. Scenario planning helps describe what might be possible for the future, not necessarily what is desired as a future. This process has two main functions: it

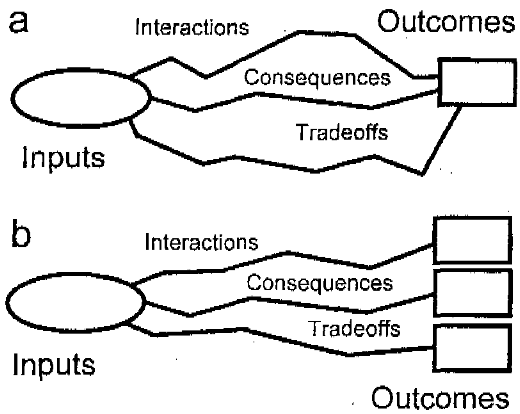

Fig. 8. Scenarios are an iterative series of "what if?" questions that explore the pathways among a wide spectrum of goals: (a) displays the consequences of a scenario reaching a desired state, which is often used in decision making, and (b) displays a scenario with a variety of outcomes determined by inputs and evaluates the consequences. This type of scenario is appropriate for use in assessments.

provides a mechanism for understanding the integration of management options, and it allows people to evaluate the merits, pitfalls, and tradeoffs of ecosystem management choices.

There are two approaches to scenario planning (Fig. 8). One begins with a desired outcome and evaluates "scenarios" and discloses the consequences of reaching the desired state (Fig. 8a). This approach is useful in the decision-making process where differing approaches can be explored to achieve a desired goal or objective. Scenario planning in the assessment process uses the second approach, which describes different scenarios in terms of inputs and then evaluates the consequences, tradeoffs, and interactions (Fig. 8b). It has been described as "bounding the possible." But it also indicates how fuzzy those bounds are and what significantly affects the outcomes.

Scenario planning can display the relations among various biophysical and social elements. Scenarios focus on what might happen or go awry and can provide information about robustness of an outcome, that is, the likelihood of an outcome. Synthesis through model building and scenario planning can display possible futures avoiding value-laden, all-or-nothing choices. Synthesis exposes the implied costs and benefits.

Sierra Nevada Ecosystem Project (1996) used four scenarios on population growth to project possible futures of population changes. These scenarios disclosed how population changes would possibly affect natural resources, especially the lands converted for human inhabitants. Likewise, ICRB used scenarios to evaluate different futures of the Interior Columbia River Basin based on present and hypothetical management (Quigley et al.1996).

5.5.2 Ecosystem Integrity and Resiliency

The concepts of ecosystem integrity and resiliency can foster integration among biophysical and social information. By using the characterizations of past, present, and future states of ecosystems, estimates of ecosystem integrity and resiliency can be made. Ecological integrity can be defined as system integrity, where the system is defined as the degree to which all components and their interactions are represented and functioning. An ecological system is defined in its broadest form to encompass the social as well as biophysical components. Integrity is the quality or state of being complete, a sense of wholeness (Haynes et al. 1996).

The notion of ecological integrity is rooted in scientific concepts that reflect human values (Grumbine 1992, 1994; Regier 1993). These human values include the normative goal of maintaining the integrity of a combined natural and cultural ecosystem. In this sense, a living system exhibits integrity if, when subjected to disturbance, it sustains an organizing, self-correcting capability to maintain resiliency, where resiliency is the tendency to return to some constant or cyclical state that varies within definable bounds. These end-states may include some that are judged by management and the public as being "normal and good" but may not be pristine or naturally whole (Haynes et al. 1996).

For a given ecosystem, integrity and resiliency can be estimated (Regier 1992) based on the results derived from analyzing data collected and summarized at the various scales within the assessment. Some of these measurements are exacting such as the Index of Biotic Integrity, which is based on data from sampling fish species in streams (Karr 1981). In more general terms, indices that measure preservation of wild ecosystems or monitor recovery of degraded systems or measure natural cultural mutualism in a settled landscape could be used to estimate integrity. Scenario planning, models, discriminant analysis, analysis of variance, and risk assessment are only some of the analytical techniques that could be used to provide information for these kinds of estimates. Moreover, this summarization technique could show trends in integrity and the probability that trends may change. Integrity can be estimated for individual ecosystem components such as forest, rangelands, and aquatic and hydrologic components. This could be done for subunits or an entire assessment area. Indicator variables might include the proportion of area unroaded, fire severity ratings, or predominance of native fishes.

A process similar to this was used for integrating the biophysical and aquatic attributes of the ICRB (Quigley et al. 1996). The indicator variables chosen should represent different ecosystem structures, processes, and functions. Biodiversity represented by species richness and numbers, soil productivity represented by potential vegetation and amount and quality of organic matter, and community stability represented by per capita income are examples of ecosystem components that could be used to estimate integrity and resiliency (Table 4).

If desired, different components could be weighted as to their importance to the integrity of the ecosystem. These value judgments be changed to explore how

Table 4. Hypothetical example of estimating ecological integrity and resiliency for a subregional assessment area. Various ecosystem components can be rated using indicator variables as to their integrity, the trend (increasing or decreasing), its probability that the trend will continue, and how resilient the component is.

Component[1]	Wt.[2]	Integrity[3]	Trend[4]	Probability[5]	Resiliency[6]
Current Status					
White pine presence	1	2	–1	0.8	2
Community stability	1	3	1	0.6	3
Soil productivity	1	3	0	0.3	2
Biodiversity	1	1	0	0.7	1
Water quality	1	4	–1	0.4	2
Average rating		2.6			2.0
Future					
White pine presence	1	5	1	0.2	4
Community stability	1	4	1	0.3	4
Soil productivity	1	5	0	0.3	5
Biodiversity	1	4	0	0.2	5
Water quality	1	4	0	0.1	3
Average rating		4.4			4.2

[1]Individual ecosystem component defined by assessment questions.
[2]Subjective weight given to each component. These values could be changed (1–3) to emphasize one component over another.
[3]Integrity is the quality or state of being complete, a sense of wholeness (Haynes et al. 1996). In this example 1 indicates low integrity and 5 high integrity.
[4]Trend indicates whether the integrity of the component is increasing (1), static (0), or decreasing (–1).
[5]The values (0–1) indicates the probability of the trend to continuing integrity.
[6]Resiliency is the tendency to return to some constant or cyclical state that varies within definable bounds. In this example, 1 indicates low resiliency and 5 high resiliency.

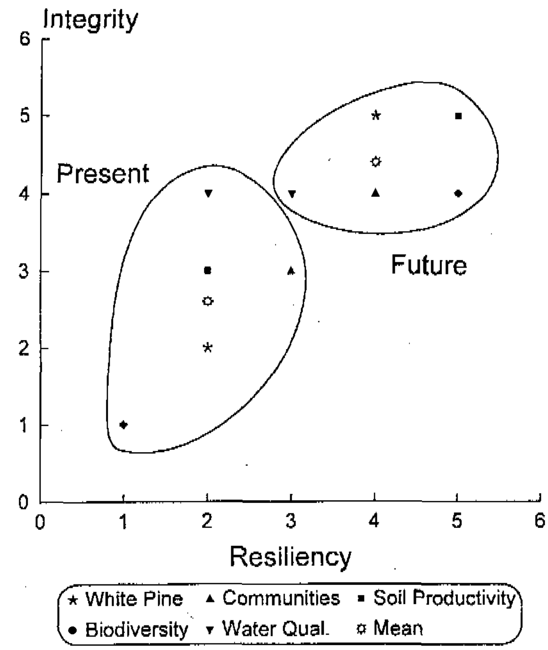

Fig. 9. Ecosystem integrity and resiliency trends can be evaluated for entire ecosystems (ovoids) and for individual ecosystem components (points). Such displays provide a graphical representation of the ratings shown in Table 4.

different ecosystem components might interact to affect overall ecosystem integrity and resiliency. Analysis results could show how ecosystem integrity and resiliency change over time (Fig. 9). Also, if this analysis was completed for different areas within a region, areas of high or low integrity could be identified.

The hypothetical example displayed in Table 4 and Fig. 9 shows that overall ecosystem integrity increased as did resiliency over a 100 year projection period (as indicated by the changes in the overall mean between the current conditions and the 100 year future). This result was based on an unweighted mean of individual ratings for each of the ecosystem elements. Different results would be obtained if weighted means from Table 4 were used. This technique would allow the exploration of different values placed on ecosystem components and the resulting effect on overall ecosystem integrity. Similar displays of the trends, probabilities (risk), integrity, and resiliency could be produced.

5.6 Data

Often data collection commences early in the assessment. Collecting data prior to developing an assessment design leads to inefficiencies and redundancies and wastes time, money, and people. Moreover, often the data collected do not provide the information for making inferences at the scale appropriate to address the questions. Data should conform to the determined indicator variables and must describe ecosystem structures, processes, and functions at a resolution appropriate for the spatial and temporal scales of the assessment. Data resolution pertains to the amount of detail incorporated in the data for a given area. For example, using a hand lens to examine a rotting log would give more detail (finer resolution) than taking pictures from an airplane. The degree of resolution generally focuses on ecosystem patterns and processes that are best addressed at a particular spatial scale.

6 ASSESSMENT PRODUCTS

Assessments can result in a variety of products. The SNEP, ICRB, New Hampshire, and SAA all produced hard copies that ranged from single volumes to multiple volumes with summary chapters. They all produced data and data tabulations. Assessments have produced less obvious results such as improving the credibility of the agency or developing partnerships among agencies and the stakeholders. The following is a tabulation of some of the products resulting from assessments (Shaw et al. 1996).

I. Technical data and information
  A. Tabular data
  B. Spatial data
  C. Meta data
  D. Models
    1. Descriptive
    2. Predictive
    3. Knowledge based
  E. List of references
  F. Glossary
II. Findings at multiple spatial and temporal scales
  A. Spatial relationships of the issues
  B. Current conditions and future trends
    1. Historic variation
    2. Scarcity and abundance
  C. Integrity and sustainability
  D. Threats and opportunities
III. Information gaps
  A. Research needs
  B. Risks and uncertainty
  C. Adaptative management opportunities
IV. Synthesis
V. Packaging (Hard copy reports, Internet, CD ROM)
VI. Relationships among employees, other agency personnel, and the public
VII. Institutional
  A. Technological and knowledge transfer
  B. Managerial and research linkages
  C. Credibility of agency
  D. Encouragement for more informed decisions
  E. More legally defensible decisions

7 ASSESSMENTS AND MONITORING

Linking assessments to monitoring programs is key in most adaptive management models. However, most monitoring occurs at the site level, and methods and tools linking multiple-scale assessments to monitoring programs have not been established or applied (Delfs et al. 1996).

The most effective way to link assessments and monitoring is to consider both programs in initial planning. This provides several advantages. Assessments identify knowledge gaps, provide baseline data, and address issues that are important for monitoring programs. During the assessment, each indicator variable used should also have a defined monitoring objective and be designed appropriately following good sampling protocols across various spatial and temporal scales (Mouat et al. 1992). All questions and subsequent inferences made during the assessment should be applicable to monitoring. If multiple scales are included in the assessment, the monitoring program should use the same scales. Therefore, by using indicator variables for both the assessment and monitoring program the monitoring program can apply any information from the assessment more effectively.

8 ASSESSMENT CONTRACT

So that both managers and the assessment teams are in accord, assessment contracts must be made between the managers and the teams at the beginning. While these contracts can take various forms, at a minimum they need to identify the desired products and the resources and time required. In the SAA process, forms were prepared to describe a specific product:

- The product name, a map, data base, model, etc.
- What question the product relates to and what was the priority of completing the product to address the question
- The primary users of the product
- The geographical extent of the product
- Listing required intermediate products
- Data security issues
- Who is responsible for the product
- Can it be completed within the time frame
- Cost
- Data source
- Intensity of data collection

Completing these product description forms resulted in a contract between the individual teams and the managers. Data and information not described by a product form and agreed to by the team leaders and managers were not included in the assessment. The rigor of this contract enabled the project to be finished on time and within budget.

9 SUMMARY

Ecological assessments have always been part of natural resource management. Current assessments for ecological stewardship are a refinement and expansion of many of the technologies and approaches that have been used in the past. Past assessments usually addressed problems of a local nature involving small geographic areas and limited numbers of stakeholders and interested participants. Today we have a better understanding of ecological systems and how they are interconnected often over extremely large areas. We now know the need for larger and more comprehensive assessments.

Our interest in maintaining ecosystems and their components has also increased. Natural resource issues are no longer local. Regional, national, and international environmental issues need to be addressed. The foundation for making decisions depends on the availability of information.

Ecological assessments using a variety of spatial and temporal scales can provide this information. Foremost, the assessment process should be designed and driven by the issues. Using the scientific method as the framework for planning and completing assessments will help avoid the most common error — collecting data before a plan is prepared. Moreover, this approach ensures that data, data resolution, and data analysis are all tailored to addressing the right question using the right temporal and spatial scales.

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