An Effective and Efficient Assessment Process[1]

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Abstract—Depending on the agency, discipline, or audience, assessments supply data and information to address relevant policy questions and to help make decisions. If properly executed, assessment processes can draw conclusions and make recommendations on how to manage natural resources. Assessments, especially large ones, can be easily influenced by internal and external forces. Completing a design prior to collecting data is the most efficient and logical way of conducting assessments. The most important step in the assessment process is to define the assessment problems or questions that address resource management issues. Questions that address well defined issues set goals for the remainder of the assessment process.

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. Collecting data prior to developing an assessment design leads to inefficiencies and redundancies and wastes time, money, and people. Moreover, often the data collected does not provide the information for making inferences at the scale appropriate to address the questions. Foremost, the assessment process should be designed and driven by the issues. 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.

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). These models usually contain a minimum of four components: monitoring, assessments, decisions, and implementation (Holling 1978; McGinty 1995; Haynes et al. 1996).

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. 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.

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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.

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.

Human hierarchies may also be defined temporally and spatially. 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.

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, mis-direct, or complicate assessments, and they are often overlooked and difficult to handle.

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. 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 sight-seeing the most common form of recreation in an area? 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.

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. 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. 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.

Ecosystems are places where a multitude of biophysical and social components interact as a whole. 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.

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). 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).

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.

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. 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.

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 eco-regions, 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.

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. 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. 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. This geographic extent may cover landscapes, watersheds, or individual project sites and specific human communities. 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). By describing ecosystems using multiple time frames, the 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.

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. 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. Lists of rare or endangered species, or other sources are starting points to identify these rare elements.

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. 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. If the indicator variable is to determine detrimental effects, then the variable should have thresholds identified. 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.

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.

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.

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.

Assessment Products

Assessments can result in a variety of products. Hard copies of results can range from single volumes to multiple volumes with summary chapters including 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

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.

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. For example an assessment contract might include the following items:

- 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

A form listing these item can form 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 would not included in the assessment. The rigor of this contract would enable a project to be finished on time and within budget.

Summary

Ecological assessments have always been part of natural resource management. Current ecological assessments 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. 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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