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Development of an Ecosystem Monitoring Plan for the Sierra Nevada

SIERRA NEVADA ASSESSMENT AND MONITORING TEAM

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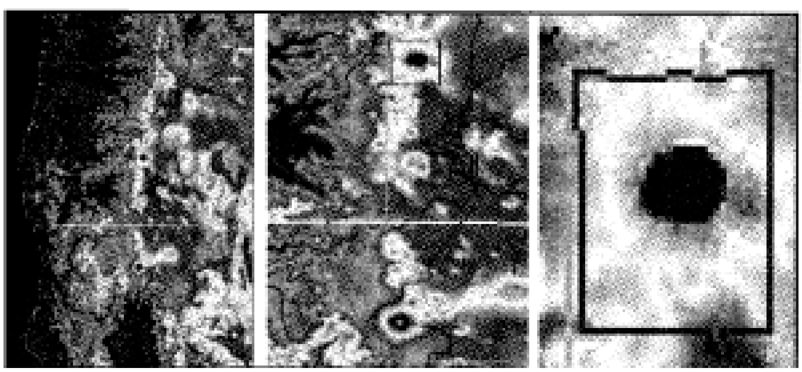
BACKGROUND

Monitoring has been identified as the critical link in adaptive management processes for dealing with uncertainty in the management of large-scale systems. The need for a comprehensive and standardized monitoring strategy for the National Forests of the Sierra Nevada was prompted by the California Spotted Owl (CalOwl) Environmental Impact Statement (EIS) (USDA Forest Service 1996). Although the EIS is now defunct, a monitoring strategy has been pursued because of the need for a coordinated monitoring effort across the ten Sierra Nevada National Forests that addresses bioregional as well as individual Forest issues. The purpose of the monitoring strategy is to implement multi-scale monitoring of biological, physical, and cultural/social elements of ecosystems to accomplish the implementation, effectiveness, and validation monitoring requirements of the National Forest Management Act. The Sierra Nevada Ecosystem Project (SNEP 1996) has also focused attention on this bioregion and raised issues relevant to land management agencies. In addition, a new multi-agency program is underway to develop a conservation framework for the Sierra Nevada and this monitoring strategy will be integrated with that effort.



Multi-Scale Monitoring

The Sierra Provinces Assessment and Monitoring (SPAM) Team began working on a comprehensive monitoring plan for the Sierra Nevada in 1996. During the first year, disjunct groups met periodically to evaluate and propose monitoring questions. In 1997, the effort developed into a cohesive approach to design a

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monitoring plan for the National Forests in the Sierra Nevada. In 1997, the team consisted of over 40 dedicated individuals from many units within the USDA Forest Service California Region and Pacific Southwest Research Station along with a variety of contributors from other agencies and academia.

The monitoring strategy has two primary goals:

1) provide a cost-effective, scientifically-based mechanism for addressing key monitoring questions; and

2) provide a mechanism by which we can incorporate the results of monitoring into future decisions and actions. These goals embrace the ecological stewardship responsibilities of the Forest Service - to be knowledgeable about the status of resources on public lands and manage for their sustainability.

The SPAM Team began development of the monitoring strategy with a review of the successes and failings of previous monitoring efforts, including National Forest Land Management Plan (LMP) monitoring in California, national reviews of Forest Service monitoring, broad-scale monitoring efforts of any kind, and the Environmental Monitoring and Assessment Program (EMAP) effort (Barber 1994; National Research Council 1995).

Past monitoring efforts, even small-scale and single-resource efforts, provide valuable information relevant to the development of large-scale monitoring strategies. Common mistakes in past monitoring efforts include: (1) past efforts have had only minimal foundations in ecological theory and knowledge with little consideration of cause and effect relationships; (2) selecting, justifying, and evaluating specific indicators to monitor has been especially problematic and not well developed; (3) most monitoring efforts have not been directly connected to the decision making process and little consideration has been given to identifying trigger points that indicate a change in management direction is needed; and (4) lack of management agency appreciation, commitment, and priority for monitoring have hindered efforts to develop, implement, and test scientifically credible monitoring strategies.

We adopted an approach to building a monitoring strategy that attempts to incorporate the best features and lessons learned from previous monitoring attempts, their critiques, and the latest ecosystem science. This strategy is based in part on the works of Barber (1994), Montgomery et al. (1995), and Noon et al. (in press). We have formed and are following a 12-step process in crafting the monitoring strategy:

- Identify monitoring questions to be answered.
- Develop a conceptual framework (model) for ecosystems addressed by the monitoring questions, consisting of key processes and their essential elements.
- Identify those actions (termed affectors) that have the potential to affect the essential elements of each process and show their link to elements in the conceptual model.
- Identify the potential biotic and physical consequences of affectors and display their links to elements in the conceptual model.
- Create an exhaustive list of candidate measures (i.e., measurable attributes) of the consequences for each process.
- Refine the questions, link them to the processes, and identify the relevant scale(s) for each refined question.
- Develop specific criteria for selecting affectors and measures for each process.
- Select a set of affectors and measures for monitoring (based on technical, operational and administrative criteria) at each scale for each question.
- Develop the quantitative definition for monitoring and evaluating each measure and affector (including field testing to the extent necessary).
- Test data collection and evaluation procedures.
- Develop an adaptive management model for the monitoring effort.
- Implement monitoring and evaluation procedures.

THE 12-STEPS

The SPAM team has not completed all of these steps, though the majority of component groups have worked through Step 6 and the approach has been outlined for Steps 7-9. Because the monitoring strategy encompasses biological, physical and social/cultural realms, the descriptions below are fairly general. Examples from the aquatic biosphere and hydrosphere are provided for the steps that have been completed. These examples should be considered preliminary, as they have not been formally reviewed and will not be finalized until the bioregional scale of the monitoring plan is complete later this year.

Identifying the Questions (Step 1)

Developing monitoring questions is the first in the 12-step process. The questions generally concern changes in ecosystem attributes. The intent of the questions is to identify ecosystem attributes of concern, determine how ecosystem attributes change, and identify whether or not the observed change is of concern. Our questions came from three sources: CalOwl Revised Draft EIS (RDEIS) (USDA Forest Service 1996), LMP Monitoring plans, and the Sierra Nevada Ecosystem Project (SNEP 1996). To date, over fifty questions have been gleaned and condensed from these three sources.

Aquatic Biosphere and Hydrosphere Questions (Step 1)

Q-1. Are priority biological, physical, and chemical attributes, processes, and functions of aquatic ecosystems degraded, maintained, or restored in the Sierra Nevada? Including:

- *biotic integrity of aquatic diversity management areas (Moyle, et. al. 1996)*
- *anadromous fish populations*
- *resident fish populations*
- *priority species and habitats*
- *major drainage water quality*

Q-2. What is the compliance and effectiveness of water quality management during activities?

Q-3. What is the relationship between the distribution, magnitude, and rate of disturbance and priority biological, physical, and chemical attributes, functions, and processes in aquatic ecosystems?

Developing the Conceptual Model (Steps 2-6)

The evolution of the study of ecology and, more specifically, large-scale systems, has indicated a continually growing appreciation of the complexity of the natural world and the importance of spatial and temporal scales (O'Neill et. al. 1986). Current scientific thinking recognizes that in order to understand system structure and function it is important to recognize the spatial and temporal scales relevant to the specific ecological process under consideration. System structure and function develop under particular disturbance conditions, and the ability of a system to absorb the effects of a disturbance and maintain itself, is a measure of the resilience of a system. Traditionally, human management has resulted in systems that have reduced resilience to change as a result of reductions in spatial and functional heterogeneity. Humans are recognized as central components within the concept of ecosystem management and sustainability. However, ecological systems have limits. Recognizing that and maintaining system function in perpetuity must be a primary objective of management.

A detailed conceptual model of the system to be monitored is recognized as an essential component of a scientifically credible monitoring strategy. A conceptual model expresses ideas about components and processes deemed to be important in a system, along with some preliminary thoughts on how the components and processes are connected - it is a statement about system form and function. The second step in our 12-step process was to develop a conceptual model of Sierra Nevada ecosystems. In addition to developing the framework for the conceptual model, we imbedded within it the next four steps (3-6): the activities (e.g. management actions) of interest, their potential consequences, possible measures of consequences, and the linkages among all these entities. Our conceptual model illustrates the relationships between anthropogenic activities, monitoring measures, and ecosystem sustainability in the Sierra Nevada. We refer to our conceptual model as the "Sierra Nevada Ecosystem Process Model" (SNEPM). The SNEPM model is hierarchical, with three echelons, and is based on the concept of holons (Figure 1). The term holon was coined by Koestler (1967, 1969) after the Greek word holos, meaning a whole (plus the suffix `on', as in proton, suggesting particle) (O'Neill et al.1986). We view ecosystems as holons consisting of many components interacting in a nonrandom manner, with the tendency to display a degree of autonomy and individuality, and to function as an integrated part of some greater whole.

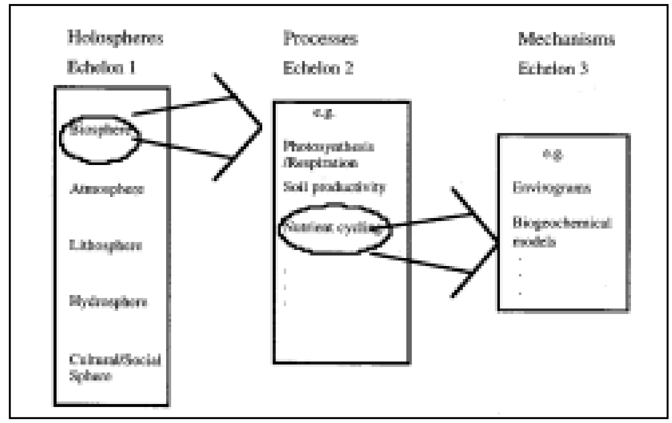

Figure 1. Hierarchy of the Sierra Nevada Ecosystem Process Model

The first echelon consists of a simple model showing the framework of five holospheres: atmosphere, biosphere, lithosphere, hydrosphere, and cultural/social sphere (Figure 2). The second echelon consists of a detailed model for each holosphere. The third echelon consists of models depicting detailed relationships among elements within holospheres. The holosphere models (the second echelon) depict the information generated during Steps 2-6 of our approach to developing the monitoring strategy. For each holosphere, we identify: 1) the *key processes* that perform the major material and energy transfers in the system; 2) the factors that enable or regulate the processes, which we refer to as *essential elements;* 3) the possible *anthropogenic affectors* (referred to as *affectors* from here on) that could potentially alter the essential elements associated with each key process; 4) the *consequences* of the influence of each affector on essential

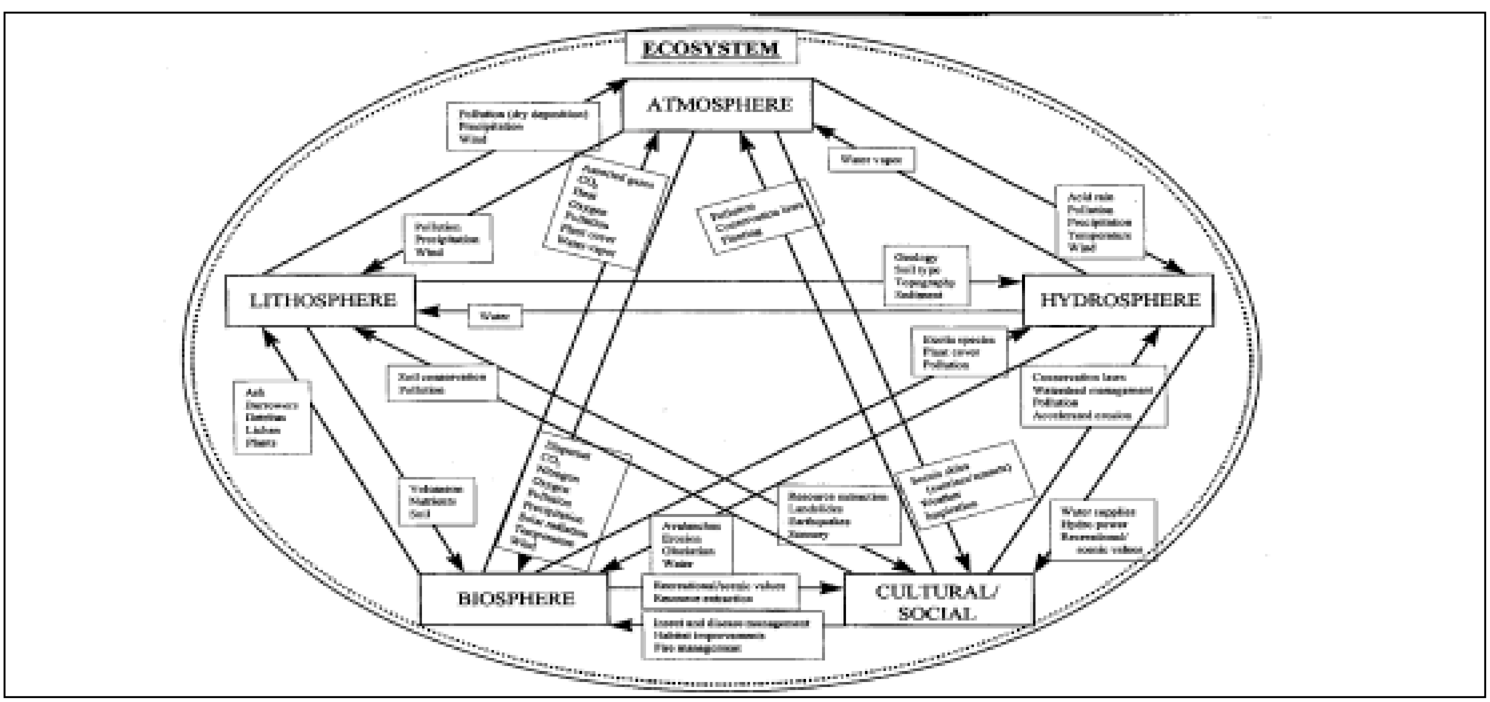

Figure 2. Sierra Nevada Ecosystem Process Model, first echelon, displaying the five holospheres and some of the elements exchanged

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Aquatic Biosphere and Hydrosphere Processes and Example Elements (Step 2)

Biosphere		Hydrosphere	
Processes	**Elements**	**Processes**	**Elements**
photosynthesis	CO_2, solar energy	infiltration	ground cover, porosity
nutrient cycling	microclimate, biomass	transmissivity	geology, topography
individual vitality	cover/water availability	storage dynamics	permeability, rock type
individual behavior	experience, mating system	capture / retention	soil water, upland veg
population dynamics	genetic diversity, age ratios	runoff / flow regime	channel type, precip.
interspecific interactions	species pool, nutrients	evapotranspiration	leaf area, soil cover
evolution/genetic dynam.	gene flow, mutations	chemical processes	flow, temperature
community dynamics	disturbance regime, species pool	nutrient cycling	solar energy, biomass
trophic dynamics	solar energy, primary productivity	water temp. regime	air temp., substrate
mixing / turnover	density gradient, wind		

elements; and 5) measurable attributes of the consequences that could be monitored; these we refer to as *measures.*

Aquatic Biosphere and Hydrosphere Affectors (Step 3)

- Acidification
- Air pollution
- Biomass harvesting
- Channel alteration
- Chemical poisons
- Climate change
- Cumulative watershed effects
- Dams/diversions
- Domestic livestock grazing
- Erosion
- Fire suppression
- Flooding
- Foothill development
- Human recreation/presence
- Hunting/gathering
- Impermeable surfaces
- Introduction of exotics
- Introduction of foreign genotypes
- Introduction of hatchery fish
- Mining
- Noise
- Human population growth
- Proximity to urban areas
- Restoration
- Roads and landings
- Ski area development
- Timber harvest/vegetation management
- Urbanization
- Ultraviolet radiation
- Water pollution

Hydrosphere Consequences and Measures (Steps 4-5)
An example for the "Runoff/Flow Regime Process"

Consequences (of Affectors)
Change in channel type and condition
Change in floodplain connectivity
Change in runoff regime
Change in vegetation community mosaic
Change in vegetation composition and structure
Change in water quality
Potential Measures
Hydrograph patterns
Aquatic biota distribution and abundance
Distribution, composition, structure of vegetation community mosaic
Ditch elongation
Electrical conductivity
Elevation of the water table
Temperature

Criteria for Affector and Measure Selection (Steps 7 & 8)

The task of selecting the affectors and measures to be monitored from an exhaustive list of potential measures requires the application of evaluation criteria, as well as review of the conceptual model to maintain a clear understanding of relationships between affectors, measures and processes. Three types of criteria are recognized: technical, operational, and administrative. The criteria were derived from a variety of sources, including published literature and SPAM Team discussions. The following are some examples of criteria that can be used for all holospheres.

Technical
- How sensitive is the measure to affectors and changing conditions?
- Is change detectable at the scale of interest?
- Can trigger points be identified?

Operational
- What is the availability of existing data?
- What is the relative cost per unit effort?
- Are there existing methods and protocols for the measure?

Administrative
- Is using the measure consistent with formal agency direction?
- Is it useful for other agency information needs?
- It is easy to interpret by nonscientists?

Quantitative Definition of Affectors and Measures (Step 9)

The process of answering a particular monitoring question involves many steps, from linking the question to an ecosystem process, to selecting a measure (or measures) that address the question, to developing a statistically sound sampling design for estimating the condition and the status or trend of the affectors and measures. The SPAM Team developed a list of descriptors that should be quantified for each monitoring question and measure including: 1) list of related processes, 2) null hypothesis, 3) alternative hypothesis, 4) spatial scale description, 5) temporal scale description, 6) experimental design, 7) metric and effect size, 8) data analysis approach, 9) data interpretation, 10) geographic emphasis areas, l l) cost estimate, 12) responsibility, and 13) data management.

NEXT STEPS FOR BIOREGIONAL SCALE MONITORING

The SPAM Team currently consists of eight components: Atmosphere, Lithosphere, Terrestrial/Riparian, Aquatic, Cultural/Social, LMP Assessment, Data Management, and Internal/External Coordination. The first five components pertain to subject areas of the monitoring questions; the last three components pertain to the infrastructure needed to facilitate the development

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and implementation of the monitoring strategy.

The goal during the next year is to develop the bioregional scale questions (including implementation monitoring questions) through the quantitative definition of each of their measures (i.e., Steps 1-9), so we are prepared for pilot implementation of monitoring for those questions in 1999 (Step 10). As this strategy is developed, we will solicit input and participation from other federal and state agencies with interest or jurisdiction in the Sierra Nevada. Our objective here will be to develop standardized sampling designs and protocols so that data can be shared and compared across the Sierra Nevada bioregion. In addition, we will be developing an adaptive management model for use in interpretation of monitoring results (Step 11). Embracing an adaptive management approach, whereby results of monitoring are used to learn from and improve subsequent management, enables management to proceed in the face of uncertainty.

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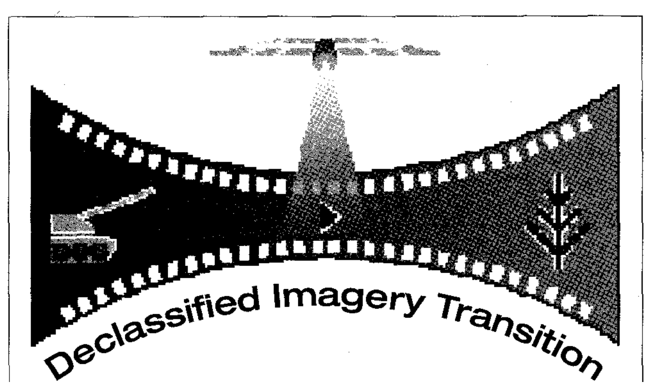

Sometimes 1 wonder why we are not still dancing on the rooftops over the end of the Cold War. Are these great times or what? Look here: http://edcwww.cr.usgs.gov/dclass/dclass.html