A Strategic Framework for Science in Support of Management in the Southern Sierra Nevada Ecoregion

A Collaboratively Developed Approach

June 10, 2009

for Adopted by Craig Axtell, Superintendent
Sequoia and Kings Canyon National Parks

Adopted by Tina J. Terrell, Forest Supervisor
Sequoia National Forest/Giant Sequoia
National Monument

Developed by:
The US Department of Interior National Park Service, Sequoia/Kings Canyon National Parks
The US Geological Survey, Western Ecological Research Center
The USDA Forest Service, Pacific Southwest Research Station
The USDA Forest Service, Sequoia National Forest/Giant Sequoia National Monument

A Strategic Framework for Science in Support of Management

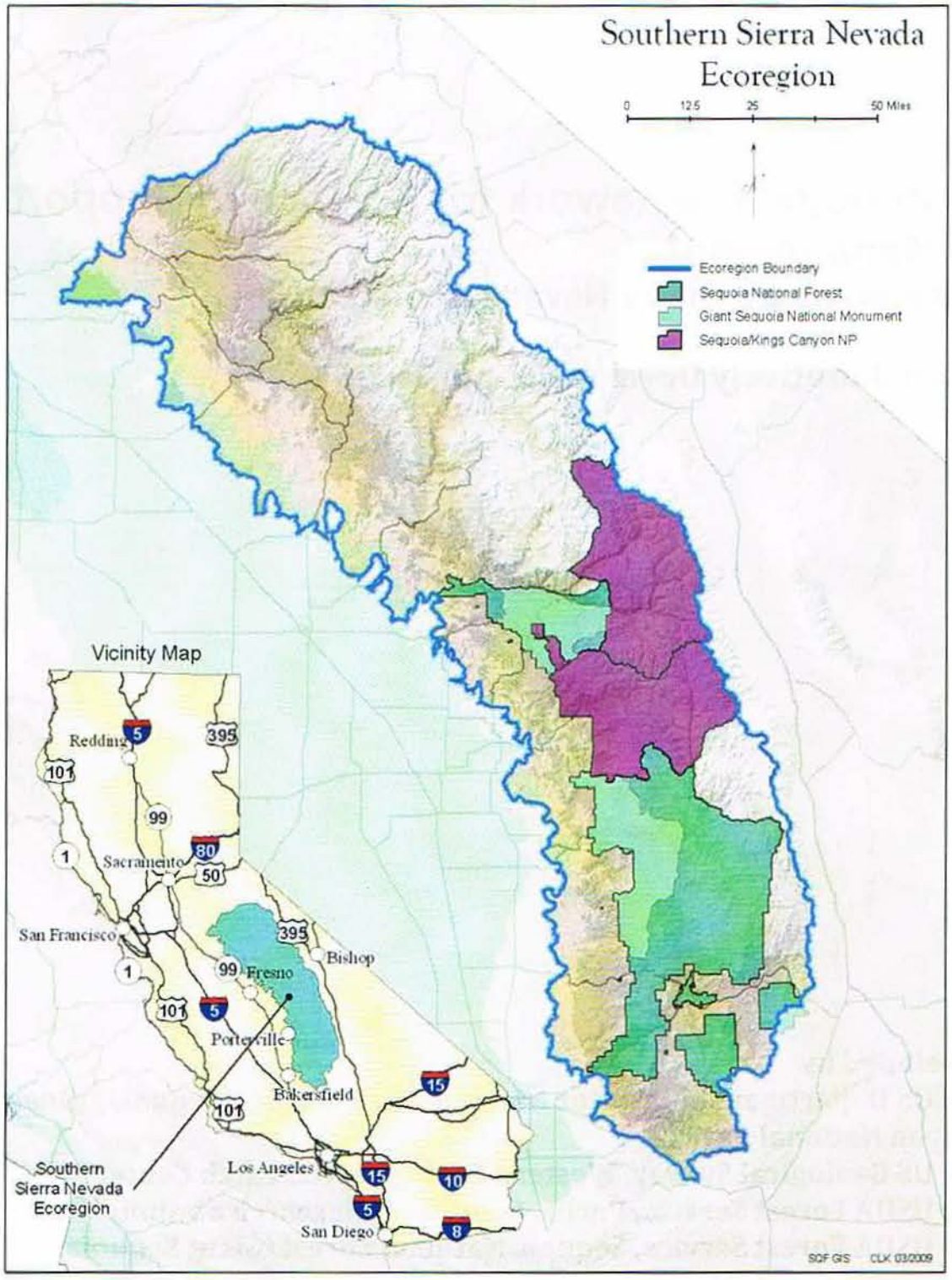
In the Southern Sierra Nevada Ecoregion

A Collaboratively Developed Approach

Developed by
The US Department of Interior National Park Service, Sequoia/Kings Canyon National Parks
The US Geological Survey, Western Ecological Research Center
The USDA Forest Service, Pacific Southwest Research Station
The USDA Forest Service, Sequoia National Forest/Giant Sequoia National Monument

April 14, 2009

Figure 1


Southern Sierra Nevada Ecoregion
0 12.5 25 50 Miles
Ecoregion Boundary
Sequoia National Forest
Giant Sequoia National Monument
Sequoia/Kings Canyon NP
Vicinity Map
Redding
Sacramento
San Francisco
Fresno
Bishop
Porterville
Bakersfield
Los Angeles
San Diego
Southern Sierra Nevada Ecoregion
SQF GIS CLK 03/2009

Strategic Framework for Science in Support of Management

Drafting Team

John Exline
District Ranger, Hume Lake Ranger District, Sequoia National Forest/Giant Sequoia National Monument

David Graber
Chief Scientist, Pacific West Region, National Park Service

Nathan Stephenson
Research Ecologist, USGS Western Ecological Research Center, Sequoia-Kings Canyon Field Station

Peter Stine
Program Manager, Principal Research Scientist, Biogeographer, Pacific Southwest Research Station/ Sierra Nevada Research Center

Charisse Sydoriak
Chief, Resources Management and Science, Sequoia and Kings Canyon National Parks

Debra Whitall
Social Scientist, US Forest Service, Region 5

Rebecca Reynolds
President, Rebecca Reynolds Consulting

TABLE OF CONTENTS

Conclusions and Recommendations

This document is a strategic framework for management-directed scientific inquiry. It serves as a foundation for a comprehensive, coordinated approach for integrating science into regional land management activities. The framework's purpose is to guide the creation of a work plan. The development of the work plan is an iterative process that will evolve through collaborative learning.

To implement the strategic framework and the development of the work plan, we recommend a full time professional be dedicated – a person to integrate science and management and to ensure that this effort succeeds.

Whether or not a position is dedicated, we recommend the following framework elements as critical initial actions in this overall effort.

Focus on answering the following questions:

- Which ecosystem elements are important and time sensitive to track?
- Where on the landscape should actions be taken now?
- How does each agent of change affect important ecosystem elements?
- Which agents of change can be slowed and why?
- What tools and approaches further effective human response to known agents of change?

Take swift action to:

- Create a range of plausible future scenarios
- Create an information clearinghouse

In addition to the above, we need a process to engage scientists and managers that will result in a major transformation in thinking about public land management. Climatic change is unlike any other challenge yet encountered by public land managers. The effects of climatic change on resources will be strongly influenced by interactions with other agents of change. The way we manage landscapes will change radically. This situation demands novel thinking and creative management actions. We must avoid committing to a single path or solution and assuming that old ways will suffice. The process to transform thinking will take a substantial commitment of funds and time to achieve.

Introduction

The U.S. Department of the Interior National Park Service, Sequoia and Kings Canyon National Parks (NPS); U.S. Geological Survey, Western Ecological Research Center (USGS); the U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station (PSW); and Sequoia National Forest/ Giant Sequoia National Monument (FS) have entered into a Memorandum of Understanding (MOU) to collaboratively develop a program of research, resources management, and public education to help inform our collective response to climatic change effects on ecosystems of the southern Sierra Nevada. Although our area of interest encompasses the west slope of the Sierra Nevada ecoregion from Yosemite National Park south to Tehachapi Creek (see Figure 1), the pilot area involves only the area of the MOU signatories. We intend to coordinate with other agencies and entities that are not formal signatories to the MOU but that are included in this geographical area.

Purpose

This Strategic Framework represents an early product of the joint agreement, and outlines the priority science information needs related to the southern Sierra Nevada region. The Framework has been developed strategically, and thus will act as a conceptual guide rather than a detailed prescription for specific science projects. It is meant to help scientists and managers plan, prioritize, fund, execute, and report the results of research aimed at addressing priority information needs relevant to the management of public lands in the face of an uncertain and unprecedented future. The Strategic Framework will lead to relevant and useful science products that help the broad community of policy and decision-makers, resource practitioners, scientists, and citizens to make sound decisions and take effective action in varied and uncertain situations.

Background

The southern Sierra Nevada ecoregion is of great importance regionally, nationally, and globally, not only for its abundant recreational opportunities, but as the main source of water for California's thriving agriculture, energy production, and domestic water needs. The ecosystems of the southern Sierra Nevada ecoregion provide an array of other ecosystem services to the people of California, the country, and the world. The southern Sierra Nevada ecoregion is relatively intact, and the headwaters and middle watersheds are almost entirely administered for public benefits. However, landscape changes, including the effects of global climatic change, shifting fire regimes, patterns of human land use, and other ecosystem agents of change have already affected the integrity of this ecoregion's natural, cultural, and socio-economic resources and assets.

Global climatic change has already caused significant regional warming and consequent changes in snow hydrology that, in turn, may affect the long-term sustainability of forest, monument, and park resources. Other major drivers of changes in ecosystem structure and function include habitat fragmentation, encroaching urbanization, shifting fire regimes, invasive species, and increasing air pollution, among others. All of these agents of change interact with one another, and affect ecosystems at broad spatial scales, usually requiring that responses also be planned and executed at broad spatial and temporal scales.

Guiding Principles

The following Guiding Principles helped provide a foundation for the Strategic Framework's creation, and may further help guide its implementation.

- Climatic change cannot be addressed in isolation. The effects of climatic change on resources will be strongly influenced by interactions with other agents of change. Therefore this document focuses on all agents of change, even though climatic change is the overarching theme.

- Resource management decisions must be based on sound science, therefore this Strategic Framework focuses on science relevant to managers. Implementation of this Framework requires continuous, iterative collaboration between scientists and managers.

- Humans are both agents of change and the recipients of the outcomes of those changes. These changes affect us in the short and long term: socially, economically and culturally. Because of this inextricable link, this Framework provides a blueprint for collective action.

Strategic Framework Approach and Structure

Members of the science and land management communities and the public met over two days in September 2008 at the Southern Sierra Science Symposium. The work of the second day resulted in a series of questions related to a broad spectrum of information needs. These questions provided a foundation for the development of the Strategic Framework. A synthesis of the symposium results is included at the end of this document.

A challenge in developing this Strategic Framework was deciding on an organizational structure that would be both useful and transparent to all interested parties. We considered structures based on agents of change, on scientific disciplines, on science activities, and others. We finally chose to organize around the broad classes of information that managers need to make decisions and act. We felt this best allowed us to maintain a sharp focus on the questions most relevant to managers, policy makers, and the public. Specifically, several broad questions emerged regarding southern Sierra Nevada ecosystems and their management:

• First, what is happening, why is it happening, and what does it mean? This question looks at the past and the present. For example, has a particular species been declining? If so, why? And if so, is the decline great enough to be cause for concern? Informed decision-making and management actions are impossible without this foundational information.

• Second, what is a range of plausible futures we might face? This question complements the preceding question by looking to the future. Again, informed decision-making and management actions are impossible without this foundational information

• Third, what can we do about it? This question is about action. If the foundational information answering the preceding two questions indicates that undesirable changes are happening or are likely to happen, what options do we have for adaptation or slowing agents of change?

• Fourth, how can relevant information be made accessible to all who desire it? Answers to the preceding three questions, no matter how sophisticated and potentially useful, are irrelevant to society if the information is not validated and made readily available in useful forms.

These questions drove the formulation of the highest level of the Framework's structure. To keep the Framework strategic, it has just four nested levels of structure. First, from the four major question areas above, broad goal statements were written that express the desired result for each. Second, each goal is subdivided into objectives. Third, under objectives come tasks, which are expanded at the fourth and most detailed level by a set of questions. These questions are meant to help guide implementation, but are not intended to be exhaustive.

For example, the first question "what is happening, why is it happening, and what does it mean?" is represented by the information needs resulting from detection, attribution, and interpretation. The goal for this question is: "We detect and describe ecosystem changes across a range of spatial and temporal scales, can understand why change is occurring, and can interpret its significance."

The goals here have been intentionally written to describe the *outcome* sought as opposed to the *action* that will be taken, to better enable evaluation of progress. That is, plenty of detection, attribution, and interpretation could be done, but the important issue is whether or not that effort has fostered knowledge of why change is occurring, what it means, and whether or not it is significant.

The objectives under each goal express desired results that contribute to the larger goal. For example, under the goal "We detect and describe ecosystem changes across a range of spatial and temporal scales, can understand why change is occurring, and can interpret its significance," there are objectives addressing status and trends, cause and effect relationships, and context for interpretation. The objective for status and trends is "We know the status of ecosystem elements and what has changed since humans began to significantly affect Sierra Nevada resources."

Under objectives are tasks, which address the major areas of work to be accomplished to achieve each objective. For example, a task under status and trends is "develop status and trends information." The tasks are then expanded by sets of questions from which research and other projects can be developed. For example, under "develop status and trends information" falls the question "What ecosystem elements are important and time sensitive to track?"

The approach and four nested structural levels of the Strategic Framework are intended to provide useful organization to complex topics, and to give strategic guidance to the science and land management community for a coordinated science effort in the southern Sierra Nevada.

Goal 1: Detection, Attribution and Interpretation

We detect and describe ecosystem changes across a range of spatial and temporal scales, can understand why change is occurring, and can interpret its significance.

Objective 1: Status and Trends
We know the status of ecosystem elements and processes and what has changed since humans began to significantly affect Sierra Nevada ecosystems.

Assumption: Knowledge of past and present Southern Sierra Nevada geophysical and biotic diversity, ecosystem processes, and human interactions with these diverse resources can provide a critical baseline for evaluating current ecosystem integrity and function, as well as historic change over time, and can therefore prepare us for an uncertain future.

Task 1: Develop status and trends information
- What ecosystem elements are important and time sensitive to track?
- What fundamental information do we need to be prepared for the future and why is the identified information important?
- What are the descriptions, status, and trends of fundamental and influential elements in the region (e.g. water, soils, and biota)?
- What is established in the literature and what is uncertain about recent status and trends of regional ecosystem elements?

Task 2: Identify agents of change
- Are climatic change, altered fire regimes, land use, non-native invasive species, and contaminants the most significant agents of change affecting our region?
- Are there other significant agents of change?

Task 3: Identify sensitive and socially valued resources
- Who are the stakeholders and what do they value?
- What are the bases for these values, e.g. ecosystems services like water?
- How are priority resources identified?
- Are the sensitive and valued resources in an acceptable condition?

Objective 2: Understand Key Cause and Effect Relationships
We understand and can explain how particular agents of change drive changes in ecologically significant and/or socially valued resources.

Assumption: To take appropriate management action, we must be able to reliably demonstrate that the changes we observe are attributable to one or more agents of change that threaten our valued resources.

Task 1. Understand how social forces affect agents of change
- What are the demographic forces?

- What are the political forces?
- What are the economic forces?
- What are the cultural forces?
- How do these interact?
- Where are they having the greatest impact and why?

Task 2: Understand relative contributions of and interactions among the agents of change

- How does each agent of change affect ecosystem elements?
- How do cumulative impacts of the agents of change affect the ecosystem elements?
- How do the agents of change interact?
- What makes an ecosystem vulnerable, resistant, or resilient to agents of change?
- What makes human communities willing to adapt, and capable of adapting, to agents of change?

Objective 3: Context for Interpreting Findings

We understand how the rates and magnitudes of observed changes compare both to past changes (historical range of variability) and to desired conditions.

Assumption: Understanding the relative significance of observed changes is prerequisite to deciding what, if any, actions can and should be justified.

Task 1: Understand how observed changes compare to past changes

- How did regional conditions change over long periods before Euroamerican settlement?
- How do recent trends in key agents of change (climate, fire) compare to pre-Euroamerican trends?
- How do recent trends in ecosystem structure, composition, and function compare to pre-Euroamerican trends?

Task 2: Understand how observed changes compare to desired conditions

- How do current trends and conditions compare to legal mandates?
- How do current trends and conditions compare to policy?
- How do current trends and conditions compare with stakeholder values?

Goal 2: Forecast Future Conditions

We will be able to anticipate possible futures to help us develop feasible responses.

Objective 1: Models describe key relationships
We have the models needed to help explain relationships among forces driving ecosystems and their value and services.

Assumption: Scientific models help simplify and explain relationships.

Task 1: Develop models
- What models are already available?
- What relationships are not understood?
- What new models do we need?
- What should be the prioritization and sequence of their development?
- How do we validate the models?
- What needs to be parameterized?

Objective 2: Forecasts
We have forecasts of possible futures resulting from a range of environmental, socio-political, and management conditions.

Assumption: Forecasts of future conditions help managers and policy makers proactively consider the ramifications of alternative decisions.

Task 1: Run models
- What is a plausible range of future socio-political conditions?
- What is a plausible range of future conditions of agents of change, e.g. how bad will air pollution be in 2050?
- What is a plausible range of future ecosystem responses to these conditions?

Task 2: Interpret model results
- What are the possible implications for ecosystem management?
- What resources are likely to be most sensitive to agents of change?
- What resources are most vulnerable to threshold changes?
- What are the consequences of intervening in ecosystem processes to preserve biodiversity or desirable elements?

Objective 3: Scenarios
We have scenarios representing a range of possible and plausible futures.

Assumption: Scenarios are useful narratives for a range of plausible futures that form the basis for scenario planning, which is a well-developed and widely-accepted tool for coping with uncertainty.

Task 1: Create a range of plausible future scenarios

- What are the questions we want to answer?
- What are the information requirements?
- What is the best way to create plausible scenarios?

Task 2: Understand scenario utility

- What do the scenario results suggest?
- How much confidence in these results is warranted?

Goal 3: Tools and Actions

We have the tools required to take effective and efficient action.

Objective 1: Adaptation
We have the tools and action options required to effectively adapt to change.

Assumption: We have the ability to adjust to impending unprecedented change.

Task 1: Identify the current capacity for adaptation
- What tools and approaches currently further *ecosystem* resilience, resistance, realignment, and response to known agents of change?
- What tools and approaches currently further *human* resilience, resistance, realignment, and response to known agents of change?

Task 2: Develop new capability to adapt.
- What tools need to be developed to evaluate *ecosystem* resilience, resistance, realignment, and response to known agents of change under varied and uncertain conditions?
- What tools need to be developed to evaluate *human* resilience, resistance, realignment, and response to known agents of change under varied and uncertain conditions?
- How can we strategically identify parts of the landscape for different management actions?
- Where on the landscape should actions be taken now?
- What tools need to be developed to support triage?
- How do human communities develop the willingness and capacity to adapt to agents of change?

Objective 2: Curb undesired agents of change
We have the tools and action options required to help slow the rate of change.

Assumption: Society has the ability to affect agents of change.

Task 1: Identify the current capacity for slowing agents of change.
- Which agents of change can be slowed?
- How can these agents of change be slowed?
- What tools exists to slow them?

Task 2: Develop new capability.
- What information and tools need to be developed to develop capacity?
- Which management action alternatives are feasible?

Objective 3: Measure Success
Actions are evaluated to determine the degree of their success.

Assumption: We need to evaluate the success of actions to validate selected goals, objectives, assumptions, and actions and to be accountable resource stewards.

Task1: Understand the consequences of action (including no action)

- How can science improve accountability in monitoring management actions?
- What are the positive/negative, acceptable/unacceptable, cost effective/not-cost effective risks of management actions to increase ecological and human resilience to a broad range of possible futures?
- How do we know that we are being effective?

Task 2: Assess adaptation actions

- What prognostic tools exist or need to be developed to judge the probability of success?
- What diagnostic tools exist or need to be developed to measure success?
- What agency mandates or directives are not feasible?
- How do managers identify and define important management thresholds including when to start, stop, and expand management activities?

Goal 4: Information Management and Delivery

We have easy access to the growing body of information and effective ways of disseminating that information to the public, resource managers, and the scientific community.

Objective 1: Clearinghouse

A place or process will be established for the gathering, storage, and dissemination of high quality information.

Assumption: A location (physical or virtual) for readily accessible and credible information is essential.

Task 1: Select the information

- What should be the scope of the collection?
- What studies, inventories, and monitoring information, etc. already exist and where are they currently located?
- What existing data, reports, and publications of value should be digitized?
- How do we select which of these to make accessible?
- How will new information be vetted to insure its integrity, quality and transparency?

Task 2: Manage the information

- How can this information be made readily and broadly accessible?
- How will information be accessioned and catalogued?
- How should this information be served?
- How will sensitive information be secured?
- Who will be responsible for creating and maintaining the clearinghouse?

Objective 2: Effective use of information

Effective and innovative ways will be employed to disseminate, utilize, and monitor information that has been gathered to reach targeted audiences.

Assumption: Information needs and the understanding of that information varies among and between the various stakeholders and stakeholder groups.

Task 1: Identify the information needs of target audiences

- Within the target audiences, what specific groups and individuals are we trying to reach and for what purpose?
- What specific types of information do these groups and individuals need?
- How do these different needs affect the Clearinghouse?

Glossary

The Strategic Framework development team compiled the following definitions of key terms to ensure that they were used consistently and clearly throughout this document.

Adaptation – Management of ecosystems and human communities to ameliorate the undesired effects of agents of change.

Agents of change – The Sierra Nevada Ecosystem Project (1996) identified five regional systemic agents of change: rapid climatic change, altered fire regimes, invasive species, habitat fragmentation, and contaminants. In addition to these, we recognize two other important agents of change that must be understood: historic and contemporary recreational activities and land use. Sometimes agents of change are referred to as stressors.

Clearinghouse – A centrally located place, virtual or physical, where information is collected and disseminated.

Cultural resource – An aspect of a cultural system that is valued by or significantly representative of a culture, or that contains significant information about a culture. A cultural resource may be a tangible entity or a cultural practice. (NPS Management Policies, 2006)

Decision-maker – The managerial-level employee who has been delegated authority to make decisions or to otherwise take an action that would affect [public land] resources or values (NPS Management Policies, 2006). Here refers to resource managers, policy makers, and line officers.

Ecosystem – A system formed by the interaction of a community of organisms with their physical and biological environment, considered as a unit. (NPS Management Policies, 2006)

Ecosystem element – A living or non-living physical object in any ecosystem. Elements scale from individual organisms and single rocks or water bodies to species-populations and entire drainages or landscapes. Ecosystem elements are the "nouns" in the system in contrast with ecosystem processes, the "verbs."

Forecast – A projection of future conditions based on a model that is incomplete, poorly validated, or otherwise known or suspected to be imperfect. Because our understanding of ecosystems is imperfect, ecosystem models give us forecasts, not predictions.

Management intervention – A management action designed to intentionally alter ecosystem conditions.

Mitigation – [With respect to global warming] An action taken to reduce the rate of increase of greenhouse gases in the atmosphere to slow the rate of global warming. Mitigation may be in the form of reducing releases of greenhouse gases, or of sequestering those already in the atmosphere.

Natural resource – A living or non-living physical object that is derived from the natural world, such as plants, animals, soil, water and air.

Realignment – Management actions that adjust ecosystems to the reality of large, rapid, and uncontrollable environmental changes, rather than trying to restore and maintain past ecosystem conditions.

Resilience – The ability to recover from changes induced by a stress.

Resistance – The ability to resist or absorb stresses without changing greatly.

Resource – Any physical or virtual entity of limited availability. In this context, only natural and cultural resources are considered. (See Natural Resource and Cultural Resource.)

Resource practitioners (specialists) – Those who advise decision-makers and actively manage resources for accepted purposes and needs.

Response – Management actions meant to facilitate transitions of ecosystems from current to new conditions.

Scenario – A plausible and internally consistent narrative about a possible future. Scenarios may or may not incorporate model forecasts. A very simple example of a scenario: "In 2050 the Sierra Nevada is warmer and wetter, but snow is melting much earlier; wildfires are somewhat larger and harder to control; recreational visitation has more than doubled; and a previously unknown pathogen is killing giant sequoias at 10 times the 'normal' rate."

Scenario planning – Scenario planning is a strategic planning process in which managers invent and then consider, in depth, several varied scenarios of plausible futures with the objective of revealing potential surprises and producing unexpected leaps of understanding. These scenarios provide a tool for transforming the perceptions of a management team. The point is to make strategic decisions that will be sound for a range of plausible futures, and scenario planning makes this possible by considering choices in the context of possible futures.

Southern Sierra Nevada Ecoregion – A broad geographic area and the associated ecosystem types located south of the Tuolumne watershed to the Tehachapi Creek, to the east of the 450 foot contour and west of the Sierra Nevada crest.

Stakeholders – Any individual or group interested in all or parts of a particular project, landscape, or resource.

Stressor – See Agents of Change.

Target audience – A group of four broad categories of people consisting of decision makers, resource specialists, scientists, and the public.

Tool – A tool is a device or entity used to accomplish a task or facilitate more effective action; it serves as a means to an end.

A Synthesis of Questions Asked at the Southern Sierra Science Symposium

September 5, 2008

As a first step toward the development of this Strategic framework, the MOU signatories organized a two-day symposium, which took place on September 4 and 5, 2008. The first day of the symposium involved scientists presenting on a range of topics related to climatic change and the Southern Sierra Nevada ecoregion. The second day was a forum for brainstorming the range of information needs related to climatic change and other agents of change in the Southern Sierra.

The results of the symposium's second day provided a foundation for the development of the Strategic Framework. The Framework development team used this material in the development of the strategic goals, objectives, tasks and questions. The development team's synthesis work of the Symposium Day Two material is included here for reference.

The development team acknowledges the important contribution of the following individuals.

Symposium Day Two Participants
John Austin (NPS), Craig Axtell (NPS), Roger Bales (UC Merced), Klaus Barber (USFS), Colleen Bathe (NPS), John Battles (UC Berkeley), Danny Boiano (NPS), Matt Brooks (USGS), Tony Caprio (NPS), Ricardo Cisneros (USFS), Jeff Cordes (USFS), Marianne Emmendorfer (USFS), Annie Esperanza (NPS), John Exline (USFS), Carrie Fox (Fox Mediation), Linn Gassaway (USFS), Dave Graber (NPS), Steve Hanna ((USFS), Sylvia Haultain (NPS), Don Hunsaker (CSU-Fresno), Carolyn Hunsaker (PSW), Barbara Johnson (USFS), Terry Johnson (USFS) Rob Klinger (USGS), Rick Larson (USFS), Pat Lineback (NPS), Kathleen Matthews (PSW), Rachel Mazur (NPS), Connie Millar (PSW), Tom Munton (PSW), Linda Mutch (NPS), Malcolm North (PSW), Dave Parsons (USFS-Aldo Leopold Institute), George Powell (USFS), Trent Procter (USFS), Kathryn Purcell (PSW), Joe Reyes (USFS), Nancy Ruthenbeck (USFS), Brent Skaggs (USFS), Scott Stephens (UC Berkeley), Nate Stephenson (USGS), Peter Stine (PSW), Teresa Sue (USFS), Priscilla Summers (USFS), Charisse Sydoriak (NPS), Tina Terrell (USFS), Craig Thompson (PSW), Phil van Mantgem (USGS), Jan van Wagtendonk (USGS), Tom Warner (NPS), Harold Werner (NPS), Jim Whitfield (USFS), Rebecca Reynolds (RRC) - facilitator

Symposium Day One Presenters
John Battles (US Berkeley), Matthew Brooks (USGS), Ricardo Cisneros (USFS), David Graber (NPS), Nancy Grulke (USFS), Robert Klinger (USGS), Constance Millar (USFS), Mark Nechodom (USFS), Malcolm North (USFS), Scott Stephens (UC Berkeley), Nathan Stephenson (USGS), Jan van Wagtendonk (USGS), Anthony Westerling (UC Merced), Robert York (UC Berkeley)

GOAL 1: DETECTION, ATTRIBUTION AND INTERPRETATION

- In the next two years answer the following questions and update annually:
  a) What is the best available status and trends information preparing us for uncertain future conditions? At a minimum synthesize information on:
     i) the history of non-native species invasions, what makes areas vulnerable to invasion, and what preventative actions, and restoration techniques have worked;
     ii) which "transformative" invasive plants and animals currently occur in the Sierra;
     iii) what is the potential for emigration into the region by other invasives and which of these could be considered potentially "transformative;"
     iv) the distribution, amount and quality of the hydrologic resources; and
     v) existing, long-term change monitoring datasets for Sierra forest systems.
- What are the characteristics of the soils throughout the region?
- How do the basic components of the system (e.g., soil characteristics, water quality and quantity) and the system as a whole respond to changing precipitation patterns and water budget?
- How do we detect pathogens and other small organisms? How do you set up detection systems for these things?
- Can we detect landscape level changes? If so, what has changed and can these detected changes be attributed?
- What has changed in the extant ecosystems and why?
- How will the cumulative impacts of human-caused stressors affect wildlife phenology, reproduction, migration, and behavior?
- What are the cumulative effects of fire, air pollution and drought on public land resources?
- Which regional ecosystems are most vulnerable to one or more stressors and what makes each ecosystem vulnerable?
- What makes a system resistant/resilient to invasion by species that would cause transformation? What factors make a system more vulnerable to invasion?
- What gaps in knowledge exist concerning the following stressors?

Rapid Climatic Change

- How have regional ecosystem components responded to changing precipitation patterns?
- How has the regional water budget changed?

Transport and Deposition of Pollutants

- What is the spatial and temporal distribution of the various forms of pollutants and why?
- What is the relationship between ecosystem changes and human health problems caused by pollutants and why?
- How has the transport and deposition of pollutants changed over time?
- Has pollution impacted the region's natural and cultural resources and if so when, where and how?
- What have been the effects of pollution on biotic diversity/integrity and ecosystem function?

- What is the threshold amount of little known contaminants/pesticides (such as mercury) that can cause biomagnified, persistent or toxic effects on native species integrity or ecosystem function? Can these thresholds be breached in this region?
- How has the regional air quality changed over time?
- Has degraded air quality adversely impacted the region's natural and cultural resources and if so when, where and how?
- What are the synergistic affects on humans and other resources from a variety of pollutants, i.e. ozone and particulate matter?
- How is smoke from management activities affecting the health and welfare of adjacent communities over both the short and long term?
- What have been the effects on water from nitrogen and other pollutants? Is the affect exacerbated by changing precipitation caused by climatic change?

Altered Natural Fire Regimes

- What areas are at risk of catastrophic natural or cultural resource value losses due to altered natural fire regimes, disease and/or drought?
- How has fire intensity, severity, seasonality, and burn pattern changed? And what are the effects of these changes at the landscape level and on localized sensitive, high profile resources?

Invasive Species Encroachment

- What is the ecological response to species additions and deletions, as well as management actions taken to control invasives?
- What makes a system resistant/resilience to invasion by species that would cause transformation (e.g., complexity)? What factors make a system more vulnerable to invasion?
- What are the interactive effects of the invasive species with other stressors? How do the other stressors (e.g., contaminants, fire, and climatic change) interact with species invasions?
- How do we identify invasions at any scale and in all systems (e.g., disease pathogens, snails, range expansions)?

Habitat Fragmentation

- When, where, how and why has the region's natural ecosystems been fragmented by human development and use?
- What are the habitat fragmentation thresholds for sensitive species and ecosystems?

Social values, ecosystem elements and stewardship

- Are certain southern Sierra Nevada resources and their function more important than others? What is the basis for this belief?
- What are the current levels and types of ecosystem services being used and how much are these services valued by society?"
- Are the sensitive and high profile resources in an acceptable condition?

- What options exist for cost effective stakeholder continuous learning and contribution?
- How can we prevent the loss of "legacy species" (e.g., sugar, white bark and foxtail pines, and giant sequoias)?
- What makes sensitive resources and systems resistant to unacceptable change? Is that state of resistance achievable in all or only in selected locations?
- What are the cumulative effects' thresholds in the region's sensitive and highly valued ecosystems?
- What can be done now and over the long-term to make the giant sequoia, wetlands, lakes, white bark pine, and meadow ecosystems resilient or resistant to change caused by anthropogenic stressors?
- What are the necessary ecological conditions to protect giant sequoia groves from undesired fire effects?
- When, where, how and why is recreational use causing stress to sensitive and high profile public land resources?
- How has the history of human use of the Sierra Nevada, particularly since the turn of century altered the biotic integrity and ecosystem function/processes of the resources at all scales?
- How have the cumulative and/or interactive effects of political and economic pressures affected the region's natural and cultural resources?
- Which public values have changed relative to the Sierra Nevada natural resources and why?
- When, where, how and why does visitor use affect identified stressors?
- How is visitor use affected by identified stressors?
- What are the cumulative impacts of pollutants on natural and cultural resources and on people's recreation preferences?
- Are demographic changes in the Sierra foothills caused by a growing retiree population significantly changing public expectations about clear air? Is the air quality in the foothills and mountains better than in the Central Valley?
- What changes in visitation have occurred and where? Can these changes be attributed?
- What are short term and long term impacts to human health from public lands management activities (including no action decisions).
- Do livestock and or packstock (for recreational purposes) cause Sierran meadows, wetlands, or other ecosystems to cross a critical transformative threshold and remain there despite management intervention?
- What are the social and ecological benefits of livestock use in meadow ecosystems?
- Do certain exotics have social value? If so, how is this balanced with potential ecological change?
- Can public land management agencies ensure an adequate supply of energy, water, timber, and other public land resources in the future? If so, what are the assumptions?
- When and where, and under what conditions can fire be used as a management tool to protect regionally sensitive and high profile resources?
- What affect do management actions have on pools and fluxes of carbon at the landscape scale? On water yield and snow hydrology?
- How are political and economic conditions affecting current ecological conditions?
- What is the current relationship between scientists, land-use managers, and citizen stewards?
- What land-use patterns increase and/or decrease ecosystem resilience?

GOAL 2: FORECAST FUTURE CONDITIONS

- How is climatic change affecting giant sequoias?
- What are the consequences of changing climate on fire regimes, insect outbreaks, and hydrology? Can this information be used to calibrate physically based models?
- What are the effects of forest dynamics and management actions on water yield and snow hydrology?
- What makes a system resistant/resilient to invasion by species? What factors make a system more vulnerable to invasion?
- How does the Sierra Nevada water budget respond to changing precipitation patterns?
- How would giant sequoias change if a 10-year drought occurred?
- What is an expectable level of risk from fire effects to sequoia groves? Does the level of risk change based on specific grove characteristics such as past logging activities or slope?
- What is a possible range of management actions to increase ecosystem resistance and resilience to a broad range of possible futures?
- What is the spatial distribution and pattern of ozone, nitrogen, particulate matter and contaminants?
- Can future conditions be analyzed for both air pollution and climatic change simultaneously?
- How do management actions affect pools and fluxes of Carbon (particularly underground C) at large scales?
- What are the cumulative affects' thresholds in southern sierra meadows and giant sequoia groves?
- What are the cumulative effects of fire, air pollution and drought on ecosystem resilience?
- What does climatic change mean to the recreating public in the southern Sierras? Will recreation opportunities change?
- Does climatic change affect where people will live?
- How can we meet our management goals for cultural resources and sensitive species given certain fire effects, including: intensity, seasonality, and mosaic burn patterns?
- How do contaminants, fire, and climatic change interact with species invasions?
- How do we evaluate the ecological response to species additions and deletions?
- What linkages exist between ecological change and human health from pollutants (short & long term)?
- How can the relationships between scientists, land-use managers, and citizen stewards be improved?
- How do you detect pathogens and other small organisms?
- What makes a system resistant/resilient to invasion by species that would cause transformation (e.g., complexity)? What factors make a system more vulnerable to invasion?
- Does modification of existing land-use patterns increase and/or decrease ecosystem resilience: if so, how?
- How much time do we realistically have before critical transformative change occurs?
- At what point should we accept an ecologically novel or surrogate assemblage?
- Can we realistically mix up genomes to strengthen resistance? When, where and how?

GOAL 3: TOOLS AND ACTION OPTIONS

- What tools currently evaluate *ecosystem* resilience, resistance, realignment, and response to known stressors?
- What tools currently evaluate *human* resilience, resistance, realignment, and response to known stressors?
- What diagnostic tools exist to show the probability of success?
- What tools need to be developed to evaluate *ecosystem* resilience, resistance, realignment, and response to known stressors under varied and uncertain conditions?
- What tools need to be developed to evaluate *human* resilience, resistance, realignment, and response to known stressors under varied and uncertain conditions?
- What are our high-value assemblages and what are they based on (define high value and who decides). What metrics should we use to assign value? What is the management threshold?
- How can scientists, land-use managers, and citizen stewards address adjustments to management actions based on monitoring results in a timely and consistent manner?
- How can science better integrate policy, procedures, and funding structures to improve responsiveness to both human and ecological needs?
- Do existing air quality warnings affect people's activities?
- Under what conditions are public land management activities likely to have unanticipated and adverse affects on sensitive and high profile resources?
- How are the agents of change (stressors) affecting society's perspective?
- How do we know that management actions are being effective? Are they succeeding anywhere? What are the cascading effects of these efforts?
- How do managers identify and define important management thresholds including when to start, stop, and expand management activities?
- How do you set up detection systems for identifying pathogens and other small organisms?
- What are the most resistant and resilient ecosystems? Should we focus on them?
- How is human action changing the landscape? How is human use changing in response to a changing landscape?
- How can science improve accountability in monitoring management actions?
- What are the positive/negative, acceptable/unacceptable, cost effective/not-cost effective risks of management actions to increase ecological and human resilience to a broad range of possible futures?
- How does Wildland Urban Interface (WUI) management affect community and ecosystem resilience?

GOAL 4: INFORMATION MANAGEMENT AND DELIVERY

- What studies, inventories, and monitoring information is available and where is it currently located?
- What are our critical knowledge "gaps?"
- Where are the high-risk, sensitive resources located (hotspots of vulnerability)?
- How are desirable future conditions recorded and where are they located?
- Where would be a good physical location in terms of costs and access, to catalog, store, and disseminate information? How should information be organized and by whom?
- Who are the audiences we are trying to reach and for what purpose?
- What specific types of information/education do these targeted audiences need, want, and desire?
- What is the best way to synthesize, analyze, and interpret gathered information for a specific audience so that they can communicate and utilize this information amongst themselves and others?
- What existing and future products are available to help disseminate this information to targeted audiences?