RESEARCH WORK UNIT DESCRIPTION **Ref: FSM 4070**	1. Number PSW 4202	2 . Station Pacific Southwest Research Station
	3. Unit Location Albany, Davis, and Fresno	

4. Research Work Unit Title
Sierra Nevada Research Center

5. Project Leader (Name and address)
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6. Area of Research Applicability	7. Estimated Duration
Local, Regional, and International	10 years

8. Mission Sierra Nevada ecosystems are complex and our knowledge of them is incomplete. As a result, the long term outcome of any given land and resource management strategy is uncertain. We will provide assistance to land managers and policy makers by addressing this management dilemma through targeted research, emphasizing an integrated, ecoregional approach to examine particular physical, ecological, and socio-economic issues, across a range of appropriate spatial and temporal scales specific to each issue.

9. Justification and Problem Selection

The Sierra Nevada is a region that is subject to diverse contemporary land management challenges with significant scientific uncertainties surrounding key management issues. Land planning activities in the Sierra Nevada over the last fifteen years have been hampered by multiple demands, characterized by real and/or perceived conflicts. Land Managers and Policy-makers require dependable scientific information that will lead to sustaining the biological integrity and ecological sustainability goals for multiple ecosystems on Forest Service and other lands in the Sierra Nevada. This research is expected to improve our understanding of ecological interactions within forest ecosystems, to provide high quality scientific information to manage resources (e.g., multiple forest values, water quality, and amenity resources), to help define ecologically and socially sustainable management practices, to establish scientifically defensible limits to management practices to ensure viability of species indigenous to the Sierra, and to anticipate changes in forest ecosystems that may result from both natural and anthropogenic factors. A full compliment of descriptive, retrospective, and experimental research will be required to achieve these objectives.

The focus of this research unit will be upon five major problem areas:

1) Forest Function and Health
2) Conservation of Biological Diversity
3) Climate and Landscape Change
4) Water and Watershed Processes
5) Institutional and Policy Processes

Detailed descriptions of the need for research in these five areas, its relationship to other work, and the potential importance and value of the research is presented in detail below.

10. Approach to Problem Solution (Start at conclusion of item 9.) The Sierra Nevada Research Center intends to take the following actions to fulfill our intentions for problem solution:

- Collaborate with scientists and managers from other government agencies, academic institutions, and the private sector.
- Seek research opportunities for interdisciplinary, multiple investigator projects.
- Address research towards issues of ecological composition, structure, and function of the natural communities within the Sierra Nevada ecoregion; ecological research will address spatial and temporal variation and we will seek opportunities for long-term work that is necessary to better understand these ecological relationships.
- Undertake research to better assess trends among drivers of socioeconomic changes in the region and the relationships between ecological conditions and socio-economic and institutional responses.
- Conduct work in collaboration with other PSW units, Region 5 of the National Forest System, as well as other resource and land management organizations, to develop an adaptive management strategy through monitoring and experimental research to examine key elements of ecological uncertainty.
- We will seek to take research results and develop this information in a variety of ways to maximize the value for land and resource applications and promote experiments, case studies and models developed in the Sierra to be used elsewhere.

This unit will represent the collective research expertise and interests of scientists located in Fresno, Davis, and Albany as well as other scientists within the Pacific Southwest Research Station. With a full spectrum of research, from long-term, fundamental research to short-term, tactical applications, this Center is intended to support conservation, restoration, and sustainable utilization of the lands within the Sierra Nevada ecoregion.

Environmental Considerations. Research that includes vegetation manipulation, including timber harvest and fire, are often opportunistic studies that take advantage of previously planned and approved management practices being implemented by resource management agencies. If the vegetation manipulation is being done solely for the purpose of conducting research, it is categorically excluded from requiring documentation in an EIS or EA, but must be documented in a project file and decision memo (WO Amendment FSH 1909.15, Chapter 30, sections 31.1a and 31.1 [9/21/92]).

Signature	Title	Date
Recommended:	Assistant Director for Research	
	Assistant to Staff Director	
	Staff Director	
Approved:	Station Director	
Concurred:	Deputy Chief for Research	

The Sierra Nevada Research Center (SNRC) has five principal problem areas: (1) forest function and health, (2) conservation of biological diversity, (3) climate and landscape change, (4) water and watershed processes, and (5) institutional and policy processes. These reflect the majority of the ongoing research and future directions. While these problem areas are written as separate activities, in reality many of them overlap and one or more scientists work in each area. For example, water and watershed processes has components that overlap with forest function and health, conservation of biological diversity, and climate and landscape change. Institutional and policy processes could have an information input and policy feedback loop to each of the other problem areas.

The SNRC also focuses on several particular geographic areas in the Sierra Nevada where long-term, interdisciplinary research occurs, often in collaboration with National Forest System staff. One or more of the principal problem areas are addressed at each of these locations; primary examples are Blacks Mountain Experimental Forest (Lassen National Forest) established in 1999, Kings River Project (Sierra National Forest) established in 1994, Plumas Lassen Administrative Study (Plumas and Lassen National Forests) established in 2001, Lake Tahoe Basin (Lake Tahoe Basin Management Unit) in 2002, and Teakettle Experimental Forest established in 1938 (Sierra National Forest) with the Teakettle Ecosystem Experiment started in 1998. Adaptive management approaches and sustainable forest issues are part of these research efforts, and the larger ones include research approaches from plot to watershed and landscape scales.

For each of the five problem statements we present a summary of the work envisioned within the problem area using the following outline.

Problem Statement Title
- Problem Overview (brief summary)
- Subproblem Statements and brief summary
  - One or more Action Statements for a given sub-problem
  - List of current or anticipated future research studies for a given sub-problem
- Anticipated Accomplishments summary
- Future Direction in this Problem Area

The Problem overview provides a brief narrative to explain the significance of the issue(s) and the research role in addressing these issues. Subproblem statements refine the issues into discrete, tractable problems. The Action statements lay out the specific research goal for work that SNRC and/or its collaborators may address. And finally the list of current or anticipated future research studies describes the active or planned research projects that are intended to address these goals and problem areas. The anticipated accomplishments and future direction summaries describe the benefits of this research.

The details are provided as we evaluate and understand each problem today. We fully anticipate being flexible and responsive to needs as both science and management/policy evolve over time. Our goals are to maximize our scientific understanding and

productivity and address, to the extent we can, the information needs of land managers and decision makers.

Problem Statement 1. Forest Function and Health

Problem Overview

In 2003, fire in California cost $250 million to contain, destroyed 4,800 structures and killed 22 people. Fuel buildup from years of fire suppression, large-scale tree mortality from insects and pathogen infestations, and rural home construction is making fires more devastating for humans, wildlife, and forest ecosystems. Forests have also been affected by an array of other anthropogenic impacts such as invasive species, overgrazing, heavy recreational use and air pollution. While there is debate and disagreement about how to define forest health, there is wide consensus that current conditions are outside the range of recent historic variability and that restoration is needed. Restoration methods have been and will continue to be controversial. An important measure of whether restoration methods are effective or compounding current problems is to first understand how forest ecosystems function. A team of researchers at the Sierra Nevada Research Center is making significant contributions to assessing restoration efforts by defining, quantifying and understanding key functions that shape forest condition, structure, and composition.

Humans have a long history of influences on Sierran forests from Native American burning to modern fire suppression and timber harvest. Forest conditions have changed, rather dramatically in some locations, over the last 150 years. Contemporary forests contain significantly fewer larger trees; there has been a remarkable increase in surface fuels, many locations contain appreciably greater densities of small to medium sized trees, and shade intolerant species such as ponderosa pine and black oak are less common. Many of these changes are believed to result from a synergy of European settlement effects including gold mining, reduction and isolation of Native American populations, sheep and cattle grazing, water diversion, fire suppression and timber harvest. Studies also suggest that concurrent with these anthropogenic influences there has been a significant, relatively abrupt change in climate, affecting fire and vegetation dynamics. While many influences may be at work, there is little doubt that current forest conditions observed in ponderosa pine and mixed-conifer forests are unprecedented.

In the Sierra Nevada, there have been several policy proposals for restoring forests including the California Spotted Owl Report and more recently the Sierra Nevada Forest Plan Amendment and its revision. At the national level, the recently passed Healthy Forests Restoration Act states "… the Secretary shall fully maintain, or contribute toward the restoration of the structure and composition of old growth stands according to the pre-fire suppression old growth conditions characteristic of the forest type." In general both regional and national restoration policies set a goal of reestablishing pre-European conditions or a historic range of variability that predated modern fire suppression. Historical accounts, photographs, early timber inventories, and stand reconstruction all suggest, in general, forests were less dense, with more large trees and an open understory. Certainly forest conditions varied according to an array of ecological factors such as

topography or soil type. For example, forests are likely to be more densely stocked with trees at the bottom of a drainage that on the mid slope or on the ridge tops. The heterogeneity of forests (structure, composition), especially the middle elevations of the western slope of the Sierra, is significant.

The policies and historic accounts that convince us of changes in forest conditions over the last 100 years, however, provide few specifics and almost no discussion on how best to restore these conditions or assess our efforts towards these goals. Sierra Nevada forest managers are faced with a fairly specific question: using prescribed fire and/or thinning what forest structure and function would be similar to that produced by historic, frequent understory fire? Perhaps more importantly, how would this forest structure and composition vary with local topography and regional geography?

Our research goal is focused on providing forest managers with better tools for understanding and restoring Sierra Nevada forests. We believe our research serves the many Californians who enjoy Sierra Nevada forests and yet are apprehensive of the destructive power of wildfires. Research must help understand and describe a middle ground where fire has an important ecological role and its controlled reintroduction to western forests is desired and feasible.

Primary users of this information include the National Forest System, California Department of Forestry and private industry in California. Many environmental organizations, forest communities and researchers in other regions have also expressed interest. The research information produced by this unit is intended to benefit all interested parties.

Our current work in this area is focused on addressing this question using a singular but comprehensive objective: **What are fire and thinning effects on forest structure, composition, and function, and how do these effects change across spatial and temporal scales: from stand to watershed to landscapes, over time?** The array of research objectives addressed by these efforts are having and will have direct implications for National Forest System management as well as for other forest managers. The Sierra Nevada Research Center has research projects associated with each of these spatial scales. Our projects are organized by examining restoration effects on (a) structure and composition, and (b) function at three different spatial scales.

Subproblem 1. Forest Health and Function at the Stand-scale

Research on forest structure and function at the stand-level is the foundation upon which an understanding of watershed processes and landscape patterns must be built. Research at the stand scale, while still challenging, is achievable with conventional experimental design and statistical analytical approaches. Key processes at the stand level are nutrient cycling, microclimate conditions, changes in food webs, and respiration and decomposition rates. Our research areas that address this scale are geographically distributed between Blacks Mountain Experimental Forest (E.F.) on the Lassen National

Forest, the Plumas National Forest, and the Kings River Project and Teakettle Experimental Forest on the Sierra National Forest, thus covering northern, central and southern Sierra locations.

Action Statement A. Contrast the effects of wildfire, prescribed fire and thinning treatments on canopy cover, understory plants, snags, logs and live trees.

These studies are focused on understanding how disturbance-induced changes in the size, diversity and distribution of the plant community fundamentally transform an ecosystem's scaffolding (i.e. basic structure), changes that may have cascading effects on ecosystem function.

Current research studies:

- Changes in herb and shrub diversity in response to fire and thinning effects on microclimate, soil moisture and nutrients.
- Effects of fire and thinning on canopy cover, layering and foliage volume
- Changes in tree spatial structure, diameter distribution, and patch pattern
- Dynamics of coarse woody debris distribution, decay and use by wildlife
- Snag demography in eastside pine forests.
- Pattern of snag decay.
- Response of trees to prescribed fire and decay patterns of snags produced by prescribed fire.
- Decay of snags resulting from wildfire in Big Creek, Sierra National Forest**.**

Action Statement B. Compare the effects of thinning and fire on ecosystem respiration, decomposition, nutrient cycling, carbon storage, diversity and productivity.

We are focused on these core ecosystem functions because they provide a measure of state and rate changes in the flow of energy and nutrients. These basic scientific issues are fundamental building blocks for understanding ecosystem function and thus related to implications of forest management activities.

Research studies to be conducted over the next 10 years include:

- Changes in CO_2 soil respiration and carbon sequestration
- Rates and drivers of decomposition for fine fuels and coarse woody debris
- Changes in states and rate of nutrient cycling
- Effects of fire and thinning on net ecosystem productivity

Subproblem 2. Forest Health and Function at the Watershed-scale

Water is probably the most valuable commodity yielded by the Sierra Nevada mountain range and the most limiting resource on plant growth, directly affecting forest function and health. Key processes at this scale are water infiltration and runoff rates, sediment transport, and stream nutrients. Watersheds bind stand-level ecosystems by sharing this common transport medium. See also the Water and Watershed Processes Problem.

Action Statement A. Assess how different restoration treatments alter forest structure, composition and pattern across a watershed.

These studies focus on how managers might apply variable restoration treatments to provide the range of pre-European forest conditions from riparian corridors to open ridge tops.

Current research studies:

- Temporal changes of fire spatial patterns: influence on landscape mosaics (emerging properties from Cascade, Klamath, and Sierra Nevada landscapes).
- Fire history of the Little Horse Peak area, Goosenest Adaptive Management Area.
- Plant and animal population response to riparian thinning
- Effectiveness of uneven-aged, small group selection with underburning in a semi-arid ecosystem (Kings River Project)

Action Statement B. Reconstruct the effects of historical fire regimes and current restoration treatments on the spatial pattern and function of forest watersheds.

Current research studies:

- Modeling spatial and temporal fire regime patterns for designing effective short- and long-term management strategies in forests of historically frequent, low-moderate-intensity fires: integrating fire, wildlife, watershed, and other resource objectives.
- Urbanization effects on biodiversity in the Lake Tahoe watershed.

Subproblem 3. Forest Health and Function over large landscape-scales

Forest management and restoration requires large-scale planning and implementation. Certainly one of the largest scales for applying restoration is the 10 year plan for a National Forest typically encompassing up to several million acres. Processes at this scale include wildfire behavior and the effects of habitat configuration and fragmentation on wildlife population dynamics. Research has rarely been conducted at this scale because of design, expense, and implementation problems. SNRC is working closely with the Plumas and Lassen National Forests to assess the response of an array of important response variables (e.g. spotted owls, fire behavior) to fire and thinning restoration treatments on more than one million acres.

Action Statement A. Assess how restoration treatments alter forest patch size and connectivity within the landscape matrix.

Current research studies:

- Change in patch size, connectivity and heterogeneity of a forested landscape following prescribed fire and fuels treatments.
- Restoration of old-growth spatial heterogeneity following large landscape treatments.

- Modeling change in the amount and distribution of habitat conditions and wildlife populations in response to management scenarios

Action Statement B. Monitor the effects of different thinning and prescribed fire treatments on wildfire intensity and spread.

Current research studies:

- Fire behavior, extent and rate of spread in treated and untreated landscapes
- Effectiveness of defensible fuel profile zones in reducing crown fire and structure loss in wildland urban interface areas.

Action Statement C. Assess air pollution effects on forest health (plants and soil) by designing and implementing an integrated measurement program patterned after the international "critical loads" program.

A western pilot location for examination of air pollutants in western forests is located in the Kings River Project area. This work is being conducted by the Air Pollution and Global Change Impacts on Western Forests Ecosystems unit in Riverside in collaboration with this research unit.

This overall problem area of Forest Function and Health primarily focuses on fire and thinning restoration effects on forest health and function. Modern forests, however, are impacted by many factors, and all of these projects are integrated with the other problem statements within SNRC's mission. Significant impacts on forest health are also produced by invasive species (see projects under Conservation of Biodiversity), El Nino/La Nina cycles (see Climate and Landscape Change), urbanization (see Water and Watershed Processes) and social/economic factors (see Institutional and Policy Processes).

Anticipated Accomplishments and Benefits

We anticipate our accomplishments in these projects will further our basic scientific understanding of Sierra Nevada ecosystems and, in turn, address important forest management needs. We will provide specific information on assessing forest health and measuring functions that evaluate restoration practices. In particular, our goal is to focus our products and outreach around the two ecological components (structure/composition and function) within each of the three scales (stand, watershed and landscape) outlined above. Therefore we expect our accomplishments will center on the following 6 areas:

- Quantified measures of desired forest structure, composition, and condition
- Measures of ecosystem function for assessing the effects of forest restoration treatments
- Measures of how historic forest structure varied, within a watershed or as a function of topography, to guide management restoration
- Guidelines for applying different restoration treatments within a watershed
- Matrix and heterogeneity of desired conditions for a forested landscape

- ❒ Effectiveness of fuels treatments for altering wildfire behavior and fire intensity in a landscape

By focusing our research accomplishments around these 6 areas we can evaluate forest structure, composition and function at three levels often used in management planning and implementation. In practical terms, forest health will be impacted at the scales over which management plans and disturbances occur. Understanding how ecosystems function at these different scales, and how processes are nested within each other, is perhaps the only means of understanding the implications of widespread changes currently planned for and underway in Sierra Nevada ecosystems.

Future Direction in the Problem Area

In the future, our research will focus on integrating these studies across spatial and temporal scales. This will include incorporating research from our other problem statements to develop interdisciplinary models of restoration treatment effects on forest health and function. If ecosystems are indeed highly connected webs, localized changes in structure, composition and function will presumably and eventually have broad spatial and temporal ripple effects. Our long-term objective is to make the three scales described here more porous so that we can monitor and model functional effects from small plots to large landscapes.

We will also expand our research into other factors impacting forest health and function such as recreation use, air pollution inputs and effects (in collaboration with PSW Riverside and the critical loads program), and exotic and native pathogens and pests. Immediate information needs drive our near term focus towards fire and thinning restoration effects. However in the long term these other factors may have a significant effect on Sierra Nevada ecosystems. We will respond to these changes as they develop and the repercussions of such changes resonate through the ecological as well as sociopolitical systems of the Sierra Nevada.

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Problem Statement 2. Conservation of Biological Diversity

Problem Overview

The worldwide loss of biological diversity continues, largely in response to widespread habitat destruction, over-harvesting, pollution, and the accidental or otherwise inappropriate introduction of foreign plants and animals. As a result, many conservation programs have been developed throughout the world to maintain and conserve biological diversity. This need has spawned a new set of scientific disciplines revolving around the objective of conservation biology. Significant new scientific endeavors have developed in genetics, husbandry, geography, ecological modeling, etc., all directed at the creation of new insights into the conservation of biological diversity.

The Sierra Nevada ecoregion has significant geographic (latitudinal and elevational) variability, creating a notable diversity of ecosystems and organisms, including some endemic species. Although the Sierra Nevada ecoregion is still relatively intact, compared with other parts of California, several Sierra Nevada assessments have reported that many species have declined and ecosystems have been degraded in recent decades. Although there are currently very few endangered or threatened species in the region there are a number of species being considered for federal or state listing. Now is the time for management to respond before conditions potentially deteriorate to a point where management and conservation efforts become much more difficult, costly, and more complicated by conflicts with other management objectives. Thus, to conserve the biological diversity of the Sierra Nevada it will be crucial to identify the vulnerable components of biological diversity, determine the threats to diversity, understand the response of organisms and ecosystems to the threats, determine restoration and recovery techniques, perform adaptive management projects, and monitor recovery. Our efforts within this problem area will be directed at these kinds of issues.

We are describing efforts within this problem area by addressing aquatic and terrestrial issues individually. We expect that there will be overlap but we find it constructive to highlight aquatic issues apart from the remainder of the landscape because of the unique problems faced by aquatic communities.

Aquatic Conservation Problem

Several factors are particularly threatening to the aquatic ecosystems and organisms of the Sierra Nevada, and considerable work is necessary to conserve the important diversity of Sierra Nevada ecosystems and species. The aquatic, riparian, and wetland ecosystems have been substantially altered and degraded by a variety of land and water management actions in recent history including logging, water diversions, fire suppression, cattle grazing, road building, exotic species, etc. Throughout the world and especially in California, native fish, amphibians, reptiles and even invertebrates have experienced serious declines, and many species are either being considered or are presently federally listed under the Endangered Species Act (ESA). Therefore, significant attention is required to understand the cause of declines, and whether (and subsequently how) aquatic species and their habitats can be restored.

Currently, there is considerable interest in Sierra Nevada aquatic ecosystems because several assessments, notably the Sierra Nevada Ecosystem Project (SNEP), highlighted serious problems with the habitat and associated species. As a result, several environmental groups have closely watched Sierra Nevada issues and initiated specific programs highlighting the plight and restoration of Sierra Nevada organisms and their ecosystems. For example, Trout Unlimited and Cal Trout have focused campaigns towards the California golden trout and also recently petitioned for ESA protection. A number of environmental advocacy groups maintain that the Sierra Nevada aquatic ecosystems are in jeopardy and petitioned USFWS to list Sierra Nevada species including the mountain yellow-legged frog and the Yosemite toad, once common amphibians.

In 2003, the National Research Council listed 6 major national emphasis areas including biological diversity and understanding and controlling invasive species. Both of these issues are directly applicable to this problem area. In addition, many of the dams and diversions in Sierra Nevada waterways will be re-licensed over the next 10-15 years through the Federal Regulatory Commission (FERC) process. These re-licensing requirements provide opportunities for studies of and improvements in water management for native biota. The Sierra Nevada is a valued ecosystem to many interested groups and unfortunately there are a number of important scientific uncertainties pertaining to declining species and altered ecosystems that deserve considerable research effort.

To protect and maintain biological diversity we must understand how management activities and natural environmental changes affect species and their habitats, work to conserve and protect species that remain viable, and restore species in trouble. Research at the SNRC focuses on the response of populations and communities of aquatic and riparian-associated species to natural and anthropogenic influences, such as introduced exotic species, natural and regulated stream flow regimes, livestock grazing, natural and prescribed fire, and vegetation management. Invasive species are one of the four major threats to the Forest Service's mission to protect wildlife and their habitats, as defined by the Chief. The Chief noted that over half of the native species declines in the United States can be attributed to invasive species. Therefore, to understand the role of invasive non-native trout and to ultimately better conserve declining amphibian populations, the SNRC has focused considerable research effort to determine the effects of the widespread introduction of non-native trout on the native species of Sierra Nevada lakes. To maintain biological diversity in the Sierra, it will be important to not only understand species and their habitats and understand the threats contributing to their declines, but ultimately to work towards reversing the declines to maintain adequate diversity.

Sub Problem 1. Determine ecological responses of aquatic species and ecosystems to anthropogenic (human-induced) and natural environmental changes

Responses of aquatic, riparian, and wetland systems to natural and anthropogenic influences (e.g., fire, flood, drought, climate variation, fuels management, silviculture, livestock grazing, invasive species, dams and diversions) will be studied to provide information for conserving the biological diversity of Sierra Nevada aquatic ecosystems. In order to understand various ecological responses, we will also study physical, chemical, and biological interactions under conditions of minimal human-induced disturbance in aquatic, riparian, and wetland systems. This information is ultimately vital to gauge whether management activities are adversely impacting and threatening the viability of Sierra Nevada aquatic species. We will apply these foundational research findings to applied questions as they are developed.

Action Statement A. Study the effects of the widespread introduction of nonnative trout (invasive species) on the native high elevation lake fauna in the Sierra Nevada.

Recent research efforts of this group have focused on this topic. Results suggest a strong negative effect of introduced trout on the distribution and abundance of sensitive amphibians as well as other members of the aquatic/riparian community such as garter snakes, macroinvertebrates, and zooplankton. Analyses of the high elevation lake survey data examined the resistance and resilience (i.e. the degree to and the rate at which a system returns to its previous configuration once the perturbation is removed) of the alpine communities, once fish were removed. Faunal assemblages in the study lakes had low resistance to fish introductions, but in general showed high resilience once fish were removed. These analyses provide an encouraging indication that the systems will recover with some small changes in fisheries management.

Action Statement B. Examine the response of amphibians to climate variation.

Because of their sensitivity to environmental change, amphibians may be early indicators of climate shifts. In particular, changes in the phenology (timing) of activities such as breeding/egg deposition have been documented from long-term studies. The consequences of such shifts need further study. Recent studies in the Sierra Nevada suggest that some year-to-year changes in snowpack may leave some lakes without water by the end of each summer, resulting in the loss of several years of mountain yellow-legged frog tadpole recruitment. Because of non-native fish introductions to larger lakes, many amphibians are relegated to smaller shallower fishless lakes that are more prone to drought. Thus, it appears that trout introductions can also have some indirect impacts that further accentuate the climate change. Another amphibian species studied by SNRC researchers, the foothill yellow-legged frog, occurs in streams where water management affects the amount and timing of stream flows. Climate change on the west coast of the U.S. is expected to affect the amount of snow and the timing of snow melt and potentially the overall volume of flows. Management efforts for threatened and endangered species will be improved by a better understanding of how environmental changes can exacerbate anthropogenic stressors.

Action Statement C. Determine what factors are problems for other at-risk aquatic species (fish, amphibians, and reptiles) in meadow and lower elevation aquatic ecosystems.

One current study is modeling the biogeographic status and potential causal factors (including land use, climatic factors, and dams) in the decline of the foothill yellow-legged frog. Future work will focus on the mechanisms behind the identified factors for the foothill yellow-legged frog and other species.

Action Statement D. Examine the response of stream algae and invertebrates to forest restoration treatments.

The Kings River Experimental Watersheds are characterizing headwater stream food webs and the composition of algae and benthic macro-invertebrates. Stream invertebrates are routinely used as indicators of steam condition. Algae and invertebrates are being

studied both before and after mechanical thinning, prescribed fire, and the combination of thinning and fire.

Subproblem 2. Understanding the basic ecology of aquatic organisms in less disturbed habitats

Basic understanding of the natural history of species and their relationship to less altered habitats is necessary to gain a comparative understanding of processes in managed and unmanaged environments. If management activities are factors in species declines, understanding how ecosystems and species dynamics operate under natural conditions will be important in designing reserves or other restoration plans. For this reason, some research attention is focused in Sierra Nevada National Parks (Yosemite and Kings Canyon) where less disturbance has occurred historically and some management activities are no longer permitted (cattle grazing, logging, fish stocking, etc.). Research gathered in less disturbed, reference areas provides a scientific basis for future management, conservation, and restoration.

Action Statement A. Conduct long-term studies on the habitat use, survival, movement, and population dynamics of amphibians in Kings Canyon National Park and other areas of the Sierra Nevada.

The SNRC is currently examining high mountain lakes where fish stocking was terminated in the 1970s. Another project includes the first studies to determine the ages of high Sierra amphibians. Habitat models have recently been developed for several species of amphibians at both low (the foothill yellow-legged frog) and high elevations (mountain yellow-legged frog and Yosemite toad) and will be refined as new data are gathered.

Action Statement B. Follow the recovery of golden trout and their habitat within the Golden Trout Wilderness.

Recent research has focused on high mountain aquatic lake and meadows containing habitat for golden trout. In locations where previous SNRC studies have already occurred, the current management plan calls for 10 years of rest from cattle grazing. Previous SNRC work found that current levels of cattle grazing were adversely affecting the California golden trout, the state fish currently proposed for federal endangered species listing, and their high mountain meadow habitat. Such results can assist land managers in adjusting their management prescriptions to avoid unacceptable effects on species at risk.

Subproblem 3. Develop aquatic species and ecosystem conservation and restoration techniques and strategies

It is widely acknowledged that many aquatic ecosystems are degraded and aquatic species are in decline. New research on the best methods for maintaining, conserving, and, where necessary, restoring the structure, composition, function, and connectivity of

aquatic, riparian, and wetland ecosystems and species is needed. Land managers and policy-makers require reliable and defensible science to support restoration activities.

Action Statement A. Develop restoration strategies exploring differing potential management scenarios.

Potential restoration strategies will be developed using data and results from completed SNRC studies. For example, to restore mountain yellow-legged frog and other high elevation species we need to develop fish stocking scenarios that seek to balance stocking with native biota persistence. Adaptive management projects will evaluate the response of native biota to a range of different stocking regimes, in order to balance the needs of native biota with some level of recreational fishing. Other research will develop models for selecting source populations and target locations for reintroduction of the mountain and foothill yellow-legged frogs throughout the Sierra Nevada based on a synthesis of habitat associations, causal factors, and genetic data.

Action Statement B. Determine the geographic pattern and genetic variation of amphibians at different spatial scales.

Understanding patterns of genetic variation throughout the range of a species and at more local spatial scales can provide a basis for identifying conservation and management units. Management strategies will benefit greatly from solid empirical information to guide future direction. On-going research on the phylogeography of the foothill yellow-legged frog will contribute to identifying such areas for this species as well as providing information on actual and potential gene flow among river basins in the Sierra Nevada and adjacent areas. Additional work is ongoing to address biogeographic patterns and genetic variation of several amphibian species in the Lake Tahoe Basin.

Anticipated accomplishments and Benefits:

- Determine most threatened components of the Sierra Nevada necessary for conservation
- Determine the major threats to the biological diversity of the Sierra Nevada
- Determine measures to minimize or eliminate threats to species and ecosystem preservation
- Continue existing and develop new adaptive management projects to test and monitor response of species and their ecosystems to different management scenarios
- Monitor recovery and restoration projects
- Provide data specific to the Sierra Nevada to confirm or revise existing aquatic standards and guidelines for forest management
- Improved status for Sierra Nevada aquatic species

Terrestrial Conservation

Habitat loss and fragmentation and invasive species are the leading causes of the loss of biodiversity. The Terrestrial Ecology Group focuses on the response of populations and

communities of terrestrial species to natural and anthropogenic influences, such as fire and vegetation management. Basic knowledge is also required on the natural history of species and their relationship to habitat to gain a better understanding of the context of both animals and plants for their ultimate conservation. Information gathered in this area provides a defensible basis for management, conservation, and restoration. Research in terrestrial ecology centers on three interrelated sub-areas: 1) ecological response to management activities and natural processes; 2) habitat relationships; and 3) biodiversity conservation and restoration.

Subproblem 4. Ecological Response of Terrestrial Species and Ecosystems to Management Activities and Natural Processes

Understanding human-induced effects, especially management activities distinguished from natural variability of ecosystems, on populations and communities of terrestrial species is a primary emphasis of this subproblem. Research in this subarea addresses the direct and indirect effects of such influences on the structure, composition and function of vegetation, the quantity and quality of habitat, and the resulting distribution and abundance of species. Broad areas of inquiry include the effects of fire, both wild and prescribed, fire suppression, vegetation management, grazing, climate change, and recreation on Sierran species and communities. Research activities are crafted in collaboration with land managers to maximize practical learning opportunities.

Current and Potential Future Research studies to address this subproblem:

- Fire and fuels management, landscape dynamics, and fish and wildlife resources: An integrated research plan in the Plumas and Lassen National Forests.
- Effects of Fire and Thinning on Forest Health: The Teakettle Experiment.
- Characterize the effects of spring burning on avian abundance and productivity in ponderosa pine forests of the Sierra Nevada
- Avian population and community responses to different riparian buffer widths and adjacent fuels treatments on the Plumas and Lassen National Forests.
- Grazing effects on plant biodiversity and hydrology of foothill wetlands.
- Effects of Off-Highway Vehicles (OHV) on the composition and structure of vertebrate assemblages and their habitats.
- Distinguish levels of habitat quality for California spotted owls by relating forest structure and composition to owl population parameters.

Anticipated accomplishments and Benefits:

Forest managers are currently confronted with difficult management decisions that must balance the needs to maintain and/or restore old forest conditions needed by certain wildlife species while also restoring sustainable fuels conditions across forested landscapes. The work conducted under this subproblem area will directly address response of wildlife populations to forest management practices. Defensible scientific information is needed to guide the inevitable adjustments that must be made in future management decisions. Current management strategies are only beginning to reorient

forest structure and composition trajectories; clearly they will undergo further course adjustments. Given the controversial nature of old forest wildlife conservation issues, information of this kind will be crucial.

Subproblem 5. Habitat Relationships of Terrestrial Wildlife Species

Basic knowledge of natural history and habitat relationships provides the foundation for understanding the reasons behind responses to human-induced and natural influences, determining the conservation status of species, and assessing projected future change in distribution and abundance. Research in this subproblem emphasizes species-habitat relationships, estimation of important population ecology parameters, and the development of models to predict species occurrence and demographic performance. Possible models range in specificity from habitat suitability models developed from presence-absence data that predict the suitability of a site for occupancy by a species to more detailed models that address habitat quality as determined by relationships among vegetation structure and composition and species survival, reproduction, and dispersal. Habitat models are developed at multiple spatial scales ranging from the plot scale to the larger home range and landscape scales using combinations of vegetation plot data, environmental data, and remotely sensed data.

Current and Potential Future Research studies to address this subproblem:

- Describing the current distribution of fishers and other mammalian carnivores in the Sierra Nevada forests and developing regional habitat models for fishers and American martens.
- Developing plot and home-range level habitat models for fishers and the use of these models to evaluate change in micro-habitat conditions.
- Developing nesting habitat suitability models for northern goshawks and the use of these models to evaluate change in micro-habitat conditions due to human-induced and natural influences.
- Testing California Wildlife Habitat Relationship Models for Western Gray and Douglas' Squirrels within a fisher home range
- Development of a spatially explicit and habitat attribute sensitive version of the California Habitat Relationships Models (in cooperation with the Redding Silviculture Lab)
- Patterns of biodiversity, abundance and productivity of forest birds over an elevational gradient.
- Grazing effects on plant biodiversity and hydrology of foothill wetlands.

Anticipated accomplishments and Benefits:

- Assess abundance and productivity of bird species in four forest types over an elevational gradient and identify source and sink habitats.

- ❒ Develop models of habitat needs for healthy populations of coexisting bird species and predict species' vulnerabilities to habitat change.
- ❒ Examine elevational shifts in bird abundance, especially as they relate to weather conditions, and examine whether, in years of unusual weather conditions, variations in productivity are associated with these shifts.

One of the most fundamental management issues revolving around wildlife conservation is management of habitat. The Forest Service and other land management agencies/organizations have primary responsibility for this facet of wildlife conservation. Other factors may be important in wildlife conservation strategies but typically habitat is a central issue. Results from these research efforts will provide important increments of information towards assessing habitat conditions and estimating how changes in habitat due to management practices may affect wildlife populations.

Subproblem 6. Biodiversity Conservation and Restoration

Inquiry in this sub-area focuses on a broad array of issues related to the conservation and specifically restoration of biodiversity in the Sierra Nevada. Basic and applied research covers topics such as risk assessment, ecological monitoring, identification of focal species, population dynamics and viability assessment, community structure and function, habitat conservation planning, vertebrate community monitoring methods, and species and habitat restoration. Research in this subarea spans multiple spatial and temporal scales and is typically multi-disciplinary in nature, integrating landscape/ecosystem pattern and processes with ecological and socio-economic factors in the development of methods, techniques, and models for managing, conserving, and restoring biodiversity in the Sierra Nevada.

Current and Potential Future Research studies to address this subproblem:

- o Density, reproductive success and diet of California spotted owls and northern goshawks.
- o Spotted owl monitoring and demography study.
- o Abundance, distribution, and population trends of oak woodland birds.
- o Population status and habitat use of fishers (*Martes pennanti*) in the Kings River Project.
- o West Nile Virus in Spotted Owls, Great Gray Owls, and Northern Goshawks: Health Assessment, Antibody Levels and Genetics
- o Development and Evaluation of a National Protocol for Monitoring Vertebrate Populations and their Habitats at the Ecoregional Scale

Anticipated accomplishments and Benefits: (each scientist will need to frame anticipated accomplishments from the studies listed below):

- ❒ Examine long-term population trends of oak woodland birds
- ❒ Develop guidelines for the design of bird monitoring programs using point counts to determine population trends and to test for differences among treatments.

- ❒ Provide management recommendations to reduce the impact of European Starlings on native bird species.
- ❒ Estimate population size, density, survival, and reproductive rates of fishers in the Kings River Project.
- ❒ Determine the most cost-effective method for monitoring density, survival, and reproduction in fisher populations.

Research results from these lines of research on terrestrial and aquatic biodiversity will make important contributions to conservation efforts and to development of defensible management strategies that will enable continued management activities that are compatible with biodiversity conservation.

Future Direction in the Problem Area

As implications of management activities on conservation of biological diversity becomes more apparent, natural resource managers and conservation planners will increasingly demand more detailed, specific, and site-relevant information on related issues and ultimately strategies for mitigation and adaptation. The SNRC is preparing to accept this challenge through interdisciplinary scientific teams by helping to form the questions as well as inform the management solutions. From basic research to applied problem-solving, the SNRC will focus on science and technology transfer that will help managers incorporate critical concepts and innovative approaches into short- and long-term national forest stewardship.

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Problem Statement 3: Climate and Landscape Change

Problem Overview

The Earth does, and will continue to, experience climate change. Climate has a profound influence in shaping the environment, natural resources, the economy, and other aspects of life throughout the world. Until recently society generally considered climate conditions to be stable, thinking in terms of long range averages and climate being generally predictable from year to year and decade to decade. The public typically thinks of weather in terms of temperature and precipitation annual averages, comparing any given year's record to the averages calculated since weather stations have been recording data, usually only within the last 50 to sometimes 70 to 80 years. Variation in these important parameters was generally thought to be minor deviation around the stable average numbers, there was little thought given to the notion that these averages might be changing over our life time. Natural cycles of climate variability were considered to be well beyond the normal horizons of land management planning or the life span of many human generations. Why should we care about such phenomena, these were topics for geologists or paleontologists to study for academic reasons and of no real practical value for land management concerns.

However, a wealth of scientific information, from paleostudies of past variability, observations of current changes, and model-based projections of the future, shows that climate changes, while still rather small in absolute terms, are rapid and ecologically profound in many parts of the world. Furthermore, we now know with more clarity and certainty that climate change is constant and dynamic: it is part of natural cycles to which plants and animals are adapted. High mountain systems, such as the Sierra Nevada, are uniquely sensitive to anticipated global climate changes and act as "canaries in the coal mine" to provide early signals of significant climate-driven changes. During the 20th Century, average temperatures in the high Sierra Nevada have increased over 1ºC, snowpacks are melting on average 2 weeks earlier, and mountain glaciers have shrunk by 50-100%. The Sierra Nevada serves as a source of desired human resources for people living both adjacent to and distant from the Sierra Nevada. Potentially significant changes in the Sierra Nevada, thus, cascade to issues of national concern. The Sierra Nevada Research Center is responding to this environmental issue with a research team that addresses issues ranging from basic research on ecological response to climate and landscape change to applications in national forest management, conservation, and restoration.

The SNRC follows guidance set at the federal level. Acknowledging climate change as a significant environmental challenge, all climate change research for thirteen federal research agencies including the US Department of Agriculture recently has been united under the new U.S. Climate Change Science Program (CCSP). The CCSP adopted five overarching scientific goals in 2003:

Goal 1: Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the cause of observed variability and change.

Goal 2: Improve quantification of the forces bringing about changes in the Earth's climate and related systems.

Goal 3: Reduce uncertainty in projections of how the Earth's climate and related systems change in the future.

Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.

Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

The SNRC Climate and Landscape Change Research Team responds to each of these goals, with emphasis on Goals 1, 4, and 5. Although information has increased at the global scale in recent years, understanding at the regional scale, including the Sierra Nevada, has lagged considerably. Without specific information on climate change within the Sierra Nevada, and its effects on ecosystems, decision-makers and policy leaders are

poorly equipped to incorporate climate variability into natural resource management or policy.

Although there have been significant landscape-scale assessment and natural-resource management plans for the Sierra Nevada region in the last decade (e.g., the Sierra Nevada Ecosystem Project, the California Spotted Owl Assessment and Environmental Impact Statements, the SN Science Review, SN Framework for Conservation and Management, SN Forest Plan Amendment, and the Forests for the Future), climate change has not been incorporated in any of these. The significant questions facing resource managers, from the Sierra Nevada-wide to local watershed scale, become: **How do changes in climate affect ecosystems relative to better understood forces of fire, insects and disease? Managers can work with these latter disturbance factors but they need a better understanding of how climate change may influence these factors. What are the likely effects of future climate changes on natural ecosystems and human goods and services in the Sierra Nevada? What can be done to prepare for and mitigate undesired impacts at multiple scales? How do changes in climate challenge our traditional ideas and approaches to ecological restoration and sustainability?**

Because the role of climate change as an ecosystem architect is new to resource science and management, even the most fundamental questions are unanswered. To address these requires focused disciplinary and integrated interdisciplinary research and applications efforts as identified under three subproblem emphases:

Subproblem 1. High-Elevation Forest Response to Climate Variability of the Past 4000 Years

One particular emphasis for the SNRC Climate and Landscape Change Research Team is on upper montane and subalpine habitats of the Sierra Nevada. In these areas, other ecological forces such as fire and disease play lesser or more readily defined roles than in mid- and low-elevation communities, and thus the role of climate may be discerned with clarity. Because global and regional climates cycle on century-long scales, current and future changes cannot be understood except in the context of background oscillations and their ecological impacts. Research studies of the SNRC Team seeks to improve understanding of the fundamental effects, magnitudes, and interactions of century- scale climate change on high-elevation SN forests, with the following goals:

Action Statement A. Evaluate climate-induced changes in species composition, range distributions, forest structure, and function at century scales in the high Sierra Nevada

Action Statement B. Identify the role and magnitude of climate as an ecological architect relative to other landscape forces

Current and Anticipated Studies in the Next Ten Years:

- Measure and understand historic forest response to century-millennial scale climate variability.

Discrete substudies include:

a) Climate variability and high-elevation forest response over the last 4000 years inferred from limber pine in the eastern Sierra Nevada and western Great Basin

b) Effects of climate and volcanism during the Medieval Climate Anomaly and Little Ice Age, Whitewing Mtn and San Joaquin Ridge, Mono Co

c) Late Holocene dynamics of the Glass Creek Watershed, Sierra Nevada; Forest history, volcanism, and climate change

d) Quaternary biogeography of California oak species

e) The impact of Neogene climate variability on biogeography and evolution of giant sequoia from the Lund Petrified Forest, western Nevada

f) Quaternary history of the Sierra Nevada (book)

Integration: The Sierra Nevada is one of the most richly studied regions in the world for paleoenvironmental change and many projects are ongoing. The U.S. Geological Survey and local universities have had the primary research presence in this arena. Their work provides a strong foundation and environmental context, although the focus of these studies has not been at the resolution or the ecosystem components of current conservation research and concern. This community of researchers is well coordinated with the SNRC Team. The USFS Rocky Mtn Research Station RWU 4252, Ecology, Paleoecology, and Restoration of Great Basin Watersheds, centered in the adjacent Great Basin ecoregion, collaborates with the SNRC team.

Subproblem 2. 20^{th} and 21^{st} Century Climate Effects on Montane Forest and Meadow Ecosystems

Research at this scale serves both basic and applied needs. The foundational research on historic pattern and process provides the context to understand interannual- to decadal-change in the 20^{th} and 21^{st} centuries. The SNRC Team strives to understand short-term natural and anthropogenic climate changes, their effects on mid and high-elevation vegetation, and impacts relative to other ecological drivers of change. At this scale, complex interactions with human land-use, both modern, and historic, confound evaluations of ecological trends, and the SNRC Team plans studies that enable these multiple influences to be unraveled. Goals for this subproblem include:

Action Statement A. Determine the relative effects of interannual, decadal, and century-long climate change on upper montane forest and meadow ecosystems

Action Statement B. Partition the effects of climate from other drivers of landscape change, including fire, insects and disease, and floods

Action Statement C. Assess the relative impacts of future climate change to Sierra Nevada physical and ecological systems, and the concomitant effects to rural economies

Current and Anticipated Studies in the Next Ten Years:

- Forest response to 20^{th}-21^{st} century climate variability at interannual and decadal scales

- Genetic variability of whitebark pine at treeline in relation to patch age, climate variability, and vegetative layering

- Strategies for incorporating climate change into forest management, conservation, restoration and 21^{st} century forest planning; The Sierra Nevada Climate Change Assessment Project (SNCCAP) is a proposed project that will analyze implications of different climate change scenarios and assess/predict anticipated effects on different vegetation types and locations throughout the Sierra Nevada.

Integration: Scientists from the SNRC as well as from the PSW Research Station broadly have collaborative interests in a Sierrawide climate effects assessment project. Scientists in the SNRC share common questions about climate effects on forest composition and structure, fire, hydrology, amphibia, avifauna, terrestrial vertebrates, and social goods and services. Studies in Problem Area 3 overlap those in Problem Areas 1, 2, 4, and 5. Further, increasing interest focuses on climate change at this scale in California. The State of California Energy Commission has funded a new California Climate Research Center through Scripps Institution of Oceanography (UCSD) as well as a California Climate Archive at the University of Nevada's Desert Research Institute. In both cases, the Sierra Nevada is a major geographic emphasis, and the SNRC Team works closely with the lead scientists of those projects. The Nature Conservancy has similarly recently begun a nationwide initiative to study forest response to 20^{th}-21^{st} century climate change. One focal area will be the western Sierra Nevada. A similar emphasis has recently begun through the University of California Energy & Resources Program. The SNRC Team works collaboratively with these efforts.

Subproblem 3. Interpretations of Available Scientific Information and Applications to Ecological Restoration, Conservation and Management

In addition to coordinated research efforts described above, the SNRC Climate and Landscape Research Team has a major emphasis to develop the infrastructure and support to interpret and apply climate change knowledge to societal benefit. These efforts are conducted as individual case studies, as well as proposed integrated assessments that the SNRC is spearheading. Proposed interdisciplinary studies would integrate scientists within and outside the Center and involve participation from the management community with the following goal:

Action Statement A. Provide meaningful, and useful interpretations and applications to ecological restoration, conservation and management

Current and Anticipated Projects in the Next Ten Years:

(See Sierra Nevada Climate Change Assessment Project, listed under Subproblem 2)

- Climate Monitoring in the High Sierra Nevada (in association with CIRMOUNT)
- Installation of Global Observation Research Initiative in Alpine Environments (GLORIA) sites
- Science Perspectives, the new PSW Research Station Science Publication

Integration: This work is tied to efforts of the PSW Region USDA Forest Service (especially Inyo National Forest), the California Native Plant Society, Wilderness Society, The Nature Conservancy, and the Society for Ecological Restoration.

Anticipated Accomplishments and Benefits

The work charter described for this problem area outlines a body of knowledge that would provide greater understanding of the effects of climate variability at multiple scales on Sierra Nevada ecosystems. We expect to elaborate in key case studies the significance of climate as a driver of change relative to other disturbance forces. With this knowledge the SNRC team also will develop interpretations to Sierra Nevada land management, conservation, and restoration contexts, such that future management plans and policy can effectively incorporate this knowledge.

The SNRC Climate and Landscape Research Team will take a leadership role to coordinate basic and applied research on climate topics at local to international scales, including the following efforts:

- Climate Science Group, PSW Research Station
- National USFS Global Change Research Team
- Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT)
- Global Observation Research Initiative (GLORIA) sites in the Sierra Nevada

Future Direction in this Problem Area

As implications of climate becomes more apparent, natural resource managers and conservation planners will increasingly demand detailed, specific, and site-relevant

information on climate change, its ecological effects on western mountain systems, and strategies for mitigation and adaptation. The SNRC Climate Change science team, and the entire SNRC, is preparing to accept this challenge by helping to form the questions as well as inform the management solutions. From basic research to applied problem-solving, the SNRC will focus on science and technology transfer that will help managers incorporate critical concepts and innovative approaches into short- and long-term national forest stewardship.

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Problem Statement 4: Water and Watershed Processes

Problem Overview

Improved knowledge of aquatic and land interactions at local and watershed scales is essential to evaluate and design land management alternatives for stream and watershed resources. Sixty percent of California's water originates from small streams in the Sierra Nevada, yet very little information is known about how these streams are affected at the source by land management activities such as dams, diversions, logging, etc. The clean and low suspended sediment water from headwater streams is considered some of the highest quality water in the state. The quality of aquatic and riparian (near-stream) ecosystems associated with streams is directly related to the condition of adjacent uplands within their watersheds. The degradation of forest streams and their associated watersheds is often the result of non-point sources such as past timber harvesting, roads, fire suppression, catastrophic wildfires, and atmospheric deposition. Restoration of the Sierra Nevada's forest watersheds to historic or desired conditions requires active management such as reintroduction of frequent, cool fires and removal of accumulated fuel loads.

In 1996 the Sierra Nevada Ecosystem Project stated that the aquatic/riparian systems are the most altered and impaired habitats of the Sierra. While we now know that some past land management activities (e.g. excessive grazing, road construction, etc.) have had undesirable effects on aquatic/riparian systems, we do not know what is considered appropriate management for such ecosystems. The kinds and intensities of land management considered acceptable for sustainable watersheds is currently a point of debate and quantitative information is needed. The altered conditions of current Sierran forests require some management intervention but what are the acceptable approaches that will not further degrade these sensitive habitats?

Although watershed research and stream monitoring have been ongoing for some time, much of this work addresses only larger streams. Most of the available research information on effects from forest management activities (largely from the Pacific Northwest) is not applicable for Sierran forests because it comes from wetter forests subject to more severe treatments (e.g., clearcuts and wildfire). Sierra Nevada landscapes are also being stressed from climate change and air pollution. The timing of spring

snowmelt appears to have shifted within the last 50 + years to earlier in the season for many western rivers. The southern and central Sierra receives air pollution from the San Joaquin Valley, now classified as extreme non-attainment for the federal 1-hr ozone standard, serious non-attainment for the federal 8-hr ozone standard, and serious non-attainment for the federal particulate standards.

Few integrated ecosystem studies exist for watersheds, yet these are essential for understanding stream/watershed ecosystem processes and functions for changing environmental conditions and for adaptive management, thus critical information is lacking. This problem area can address the multiple stressors often acting on aquatic ecosystems in forests: tree thinning/harvesting, fire, air pollution, climate variability, land use change, water diversion, grazing, and roads. The land managed by the Forest Service provides much of the source water that other organizations address once the water gets to California's central valley and coast.

Currently the SNRC Watershed Team's focus is on an integrated, long-term watershed experiment, the Kings River Experimental Watersheds (KREW), located in the Kings River Project (KRP) and Teakettle Experimental Forest, Sierra National Forest. While located in the central Sierra Nevada, the research results are expected to be relevant to stream ecosystems within similar ecological conditions of montane forests on granitic soils in semi-arid climates of the western United States. The location of KREW between Yosemite National Park on the north and Sequoia and Kings Canyon National Parks on the south provides a unique opportunity to evaluate ecosystem characteristics and processes among similar montane ecosystems with different historic and current management practices. Gradients of conditions exist from the southern park to the northern one with moisture increasing and air pollution and temperature decreasing.

KREW is designed to: (1) quantify the variability in characteristics of headwater stream ecosystems and their associated watersheds, (2) evaluate the effect of fire and fuel-reduction treatments on the riparian and stream physical, chemical, and biological conditions, and (3) provide guidance for forest Best Management Practices. This is an integrated ecosystem project at the watershed scale and is part of a larger adaptive management study (KRP) at the landscape scale that began in 1994 as a collaborative effort between the Sierra National Forest, Southern California Edison, and the Pacific Southwest Research Station of the Forest Service to evaluate the effects of approaches for creating an uneven-aged forest similar to that present before European settlement, circa 1850. The experiment will implement treatments on headwater areas: mechanical thinning, prescribed fire, and thinning with fire.

The Organic Act of 1897 created the "public forest reservation … for the purpose of securing favorable conditions of water flows, …" This problem addresses the National Fire Plan's hazardous fuels reduction goal with regard to treatments and ecological interactions and similarly is important to the Forest Health Initiative. KREW is a Joint Fire Science Program demonstration site. The Forest Service's Strategic Plan (2003) has a goal to improve watershed condition and states the importance of maintaining riparian habitat and monitoring best management practices. This problem is the only cause and

effect research to address the aquatic ecosystem information needs identified by the Sierra Nevada Framework (2001 and 2004). On a national scale this research is relevant to multiple stressor effects as identified by the Water Environment Research Foundation and the Society for Environmental Toxicology and Chemistry. It will also provide data for Total Maximum Daily Loads should they be set for forest land under the Clean Water Act.

This problem and its elements (subproblems) have been chosen because they address both basic science needs (improving our understanding of ecosystem processes) and the needs of decision-makers requiring scientific information on which to base watershed management actions. Not only does the problem represent the importance of biological, chemical, and physical ecosystem characteristics, but it also focuses the science on the synergy of ecosystem components with each other. This creates added value to the component parts. There is a high degree of synergy between this problem and aspects of the Climate and Landscape Change and Forest Function and Health problems addressed by the SNRC; this problem also relates to the SNRC's Conservation of Biological Diversity problem.

Subproblem 1 Structure and Function of Sierra Nevada headwater streams and their associated watersheds.

For KREW, eight watersheds have been instrumented (four adjacent watersheds at two different sites). The sites have mixed conifer vegetation and represent rain on snow and snow-dominated climate systems. Baseline data collection started in October of 2002 and will continue for four years. A suite of physical, chemical, and biological measurements is necessary to understand how watersheds function and respond to both natural and anthropogenic stress or disturbance. Since not every parameter of interest can be measured, a set of characteristics is selected to represent physical, chemical, and biological structure and function. A good understanding of the variability in and interaction between these characteristics is necessary to evaluate change over time and response to management treatments (see subproblem 2).

Selected characteristics

- Water quantity and quality
- Soil erosion and condition
- Stream sedimentation
- Stream geomorphology
- Meteorology including riparian microclimate
- Nutrient (nitrogen and phosphorus) and carbon budgets and fluxes
- Air pollutant concentrations, deposition, and effects
- Fuel loadings
- Upland and riparian vegetation
- Stream biotic integrity as represented by benthic macro-invertebrates and algae
- Headwater stream food webs

Action Statement A. Quantify the variability in selected characteristics of headwater streams and their associated watersheds.

The Kings River Experimental Watersheds were designed to address this need for the Sierra Nevada. Results from the Kings River Experimental Watershed will provide heretofore unavailable empirical evidence on the varying effects of alternative treatment approaches on a variety of physical and biological elements of stream and watershed conditions,

Action Statement B. Assess air pollution effects on aquatic ecosystem components by designing and implementing an integrated measurement program patterned after the international "critical loads" program..

A western pilot location for examination of air pollutants in western forests is located in the Kings River Project area. This work is being conducted by the Air Pollution and Global Change Impacts on Western Forests Ecosystems unit in Riverside in collaboration with this research unit. Results of this work will provide important and needed information for future management decisions.

Current and Anticipated Studies in the Next Ten Years

Each of the KREW characteristics listed earlier is part of a designed study where one or more questions are addressed. In addition, many of the measurements are co-located to facilitate integration and increase the power of the analyses. For example, measurements of physical soil characteristics, fuel loadings, vegetation, and precipitation and soil water chemistry are made on a uniform grid design. With this strong design we expect additional components to be added to KREW by others; the recent addition of air pollution and critical loads research is such an example.

This subproblem relates to other SNRC Problems: Forest Function and Health and Climate and Landscape Change. KREW's hydrologic and meteorologic components address Goals 1 and 4 of the U.S. Climate Change Science Program (see Problem 3) and will integrate into the Consortium for Integrated Climate Research in Western Mountains. The air quality research is being carried out with the Forest Service's national effort on critical loads; PSW's Unit 4451 in Riverside; Region 5; the San Joaquin Air Pollution Control District; and Yosemite, Sequoia, and Kings Canyon National Parks.

University collaboration includes the University of Nevada at Reno, for soil, the University of California at Santa Barbara for invertebrates, California State University at Fresno for food webs and riparian microclimate, and the U.S. Geologic Survey for algae. It is expected that additional aspects well be added to KREW through collaboration with the new Sierra Nevada Research Institute, University of California at Merced, and the Sierra Nevada Hydrologic Observatory being proposed by the National Science Foundation's Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.

Subproblem 2. **Stream and watershed response to forest restoration.**

The Sierra Nevada landscape has been altered in many ways since the 1850s with selective timber harvesting, a century of fire suppression, extensive domestic animal grazing, and more recently increasing and diverse recreation. In addition, climate is changing and restoration back to a desired historic condition may not be entirely possible. Cause and effect experiments are necessary to know the effectiveness of restoration practices and reduce concerns about negative effects. Fire has been suppressed in the Sierra Nevada for about 100 years, thus a combination of thinning and prescribed fire is needed to efficiently move the forest condition towards a pre-suppression condition of larger trees with a canopy closure greater than 50% and an open understory. Desired forest characteristics are uneven-aged stands of a patchy nature.

KREW is a cause and effect experiment with each of the two sites having a watershed that is treated with prescribed fire, one with thinning, one with fire and thinning, and one as a control. We will be able to compare thinning and fire treatments with each other and to both the control and the combination of the two treatments on an annual basis. We also will have several years of pretreatment data that can be compared to several years of post-treatment data. This design gives the most power for determining whether observed change is due to the treatment or to normal environmental variability. Thus the findings from subproblem 4.1 are essential to this subproblem.

Action Statement A. Assess forest restoration treatments on headwater streams and their associated watersheds.

The Kings River Experimental Watersheds were designed to address this need for the Sierra Nevada with regard to mechanical thinning and prescribed fire. See subproblem 1 for the selected characteristics being evaluated.

Action Statement B. Compare and contrast management treatment effects among research locations on the west and east side of the Sierra Nevada.

Prescribed fire effects are being evaluated for ecosystem characteristics such as soils, nutrient fluxes, and carbon storage between KREW and University of Nevada studies in Little Valley, NV, and the Tahoe National Forest.

<u>Current and Anticipated Studies in the Next Ten Years</u>
For KREW, four years of pretreatment data will be compared to post-treatment data to evaluate impacts on the selected characteristics described previously. The thinning treatments will occur in 2006 and 2007 followed by fire treatments in 2007 and 2008. Post-treatment data collection will occur for five years at which time continuation of KREW will be reviewed. Continuation would allow evaluation of a second entry with fire and a more comprehensive look at cumulative effects.

This subproblem relates to other SNRC Problems: Forest Function and Health and Conservation of Biological Diversity. The stream algae and benthic macro-invertebrate

data from KREW provide a long-term data set on the diversity of these organisms for headwater streams in managed areas and can be compared to less managed headwater systems in the adjacent National Parks. Similarly, the before and after fuel loading measurements can be compared to the prescribed burning in the National Parks, and such a combined data set should address the concerns some biologists have about wildlife habitat effects from these fires.

The Kings River Project has a long-term study of the silviculture treatments (uneven-aged, small group selection with thinning between the groups) being implemented, and KREW research can benefit from such information. KREW provides the cause and effect information on soil condition, erosion, hydrology, and aquatic ecology for this larger landscape project.

Subproblem 3. Forest Best Management Practices for aquatic ecosystems

Concerns exist about negative impacts to water quality and aquatic ecosystems from forest management and restoration activities. 100 years of fire suppression and historic land management practices have created forests with high fuel loads and overstocked conditions. Many small, suppressed trees exist now rather than fewer large trees per unit area that are known to have occurred in pre-settlement forests. Much of the information on fire effects comes from hot, wildfire situations that result in these densely stocked contemporary forests of the west. Usually these studies do not have before and after data and have to use after-the-event controls. Similarly much of the data on silviculture effects comes from severe treatments such as clear cuts, seed-tree cuts, or shelter-wood cuts and is predominantly from different geologic and climatic ecosystems like the Pacific Northwest. Thus the current measures to mitigate effects on aquatic ecosystems may be inappropriate for Sierra Nevada streams.

Action Statement A. Provide guidance for forest Best Management Practices based on stream and watershed research results.

KREW will be able to provide such guidance for semi-arid, mixed-conifer forests on granitic soils on topics such as upland and road erosion, soil condition, prescribed fire in riparian areas, and mechanical thinning.

<u>Current and Anticipated Studies in the Next Ten Years</u>
Several aspects of KREW are designed to address specific uncertainties in current standards and guidelines such as the correct width of stream buffers or aquatic conservation zones and what practices are allowed within near-stream areas. The KREW study will provide much needed information for Sierra Nevada streams on prescribed fire and mechanical thinning effects for forest Best Management Practices (BMPs). Erosion and subsequent sedimentation of streams has been a long-term concern; the studies on upland soil erosion, annual sediment loading to streams, and soil condition are designed

to address regulatory needs. The vegetation measurements are designed to address differences in upland and riparian vegetation and help define what is a riparian zone for small headwater streams. The riparian microclimate study is designed to address concerns about changing water temperature, incoming light, soil moisture, relative humidity, etc. in the stream and near-stream area which provide a diverse habitat for plants and animals.

This subproblem relates to other SNRC Problems: Forest Function and Health and Conservation of Biological Diversity. The results from KREW will be of use to the Forest Service, the State of California, and private land owners, thus funding and participation reflect this interest. Some KREW watersheds contain Southern California Edison lands, and the California State Water Resources Control Board and Department of Fire and Forestry are very interested in the study. Substantial funding from the California Bay-Delta Authority is pending. The Region 5 staff and state regulatory agencies want KREW results for either support of current or revision of forest Best Management Practices.

Anticipated Accomplishments

We anticipate our accomplishments will further basic scientific understanding of Sierra Nevada ecosystems and, in turn, address important forest management needs. We will provide specific information on assessing stream and watershed condition and measuring functions that evaluate forest restoration practices. Anticipated accomplishments include the following.

- Quantification of the variability in Sierra Nevada headwater streams and watersheds for critical characteristics
- Measures of aquatic ecosystem function for assessing the effects of forest restoration treatments
- Data to calibrate and verify various models and perform predictive modeling exercises for adaptive management
    - Modeling exercises could include, stream discharge and climate change, soil erosion and sediment loads, and fire and watershed biogeochemistry.
- Guidelines for applying different restoration treatments within a watershed, especially with regard to upland and riparian areas
- Effects of multiple stressors (air pollution, land use change, climate change, grazing) on stream ecosystems

Future Direction in the Problem Area

The success of a long-term, integrated watershed study is heavily dependent on multiple investigators and funding sources. Thus increased collaboration with researchers both within PSW and outside of PSW is desirable. Opportunities exist for synthesis among this problem area, Forest Function and Health, and Climate and Landscape Change. Opportunities also exist for collaboration with other watershed studies in the Sierra Nevada (e.g., University of California's Sagehen and Blodgett facilities, National Parks, Desert Research Institute on the eastern side). This unit intends to pursue collaborative

research with partners already active in related research in the Sierra Nevada. The National Science Foundation plans to establish a network of hydrologic observatories that will stimulate study where hydrologic and biogeochemical understanding of the water cycle is currently most limited. As argued in multiple consensus planning documents, the mountain west is perhaps the highest priority for such studies. A Sierra Nevada Hydrologic Observatory is proposed, and KREW would be a core component. Another opportunity for collaboration is with organizations wanting to address issues such as water quantity and quality for entire river basins from their headwaters to their valley or coast terminus. Such work is anticipated with the California Bay-Delta Authority and should happen if a Kings River watershed organization develops.

Two other areas are expected to receive more attention in the future: air pollution research and modeling. The designation of the Kings River Project as the western demonstration site for critical loads research in the Forest Service means that more measurements will be added to areas within KREW and new collaborations will occur with air pollution specialists. KREW has been designed to provide data for multiple modeling exercises; priority areas will be fire behavior models, linked fire and biogeochemistry models, soil erosion models, and stream discharge and climate models.

PSW is not able to solely support the KREW study, thus outside involvement and support are critical to ensure the integrity and completion of the effort; state and industry support are important. To date, the National Fire Plan, Joint Fire Science Program, California Water Institute, Region 5, and California Bay-Delta Authority have contributed funds. Southern California Edison and several universities are collaborators. Increased emphasis will be put on making the research data accessible to people outside of the Forest Service as funding partners increase.

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Problem Statement 5. Institutional and Policy Processes

Problem Overview

There is a need to better understand institutional constraints and opportunities, and how public interests interact with public resource management institutions, in the context of public land decision-making. Current institutional capacities to articulate problems, participate in strategic planning and investment, and influence public land and resources decision-making varies considerably across jurisdictions and geography. The U.S. Forest Service is only one among many public agencies whose institutional processes are adapting to changes in public values and choices. There is a need to better understand institutional constraints and opportunities, and how interests interact with resource management institutions, in the context of public land decision-making.

More locally, rapidly changing demographics and economic dynamics in California and the West are impacting patterns of land use and demands for services on Sierran landscapes. Demographic and political profiles are important to anticipating the values, perceptions and beliefs held by constituents as they participate in the policy and decision-

making process. Additionally, patterns of private sector consumption and investment influence public land and resource management. Research is needed on a broad range of social, economic and institutional factors that affect landscapes and land use decisions in the Sierra Nevada and elsewhere.

Global capital investment intersects with local and regional land use decisions in ways that are not well captured by current methods of economic analysis. Non-market – or perhaps "not-yet-market" – values increasingly drive investment, consumption and public expectations. Historic commodity values compete with recreational and amenity values, as well as with other poorly measured ecosystem services, in the allocation of increasingly scarce resources. Better research is required on the methods and applications used for the valuation of non-market ecosystem services. As these methods improve, so will our ability to document and analyze how public expectations influence long-term strategic planning processes for wildlands, especially public lands in the Sierra Nevada.

Sub Problem 1. Develop appropriate research methodologies to understand institutional processes by which resource values are established as public goods.

The mission of the US Forest Service is to conserve, protect and provide a broad range of public uses and benefits. However, the definition of "beneficial use" changes with different social, political and historical contexts. The agency increasingly finds itself in a position to mediate policy and political processes through which values for public resources are established, and against which trade-offs among costs and benefits can be measured. These processes are poorly understood, both in the immediate context of Forest Service decision-making, and in the larger context of how the values of public goods are defined, established, conserved and traded.

Current and anticipated studies:

- Life Cycle Assessment Model of the Use of Wildland Biomass from Forest Thinnings for Electrical Power Generation
- Translating Public Benefits Into Public Goods: An Analysis of How Public Goods Are Established and Traded in Energy Markets

Sub Problem 2: Barriers to Investment in Private Sector Biobased Products and Energy Infrastructure

Much is made of the need to find new markets for the utilization of a new suite of forest resources issuing from forest health restoration treatments. However, very little actual data have been gathered on the broad range of activities involved. Solid research work is being conducted by other Forest Service Research Stations on fuels treatment techniques, methods and costs. Further work through FIA and PNW has led to useful and effective models that help to calculate the costs involved in moving lower value materials to markets. What requires much better focus is the policy context within which incentives are provided and barriers to market development are lifted. There is a need to analyze

comprehensively the economic and social impacts of policies that affect our ability to envision, design, and implement appropriate land management decisions.

SNRC is making key contributions to policy development efforts by investigating the effects of new policy at the strategic and tactical levels. Policy changes anticipated in the near term include:

- A biomass utilization emphasis in federal agency planning,
- State and federal biomass transportation and tonnage subsidies,
- State and federal tax breaks for investment in biobased products manufacturing,
- state-level Renewable Portfolio Standards that affect electricity prices,
- System Benefit Charges that provide capital and incentives for renewable power generation technology development,
- Private land incentives for forest health treatments resulting in usable forest products from low-value materials.

These kinds of policies can have significant influence on private sector investment strategies. For example, very little capital is flowing to the biomass energy sector because the rules for implementation of Renewable Portfolio Standards in many states are not yet well defined. Similarly, rules and policies affecting the trade of renewable energy credits among utilities appear to have a strong influence on capital investment in biomass power. The roles of federal lands and federal policies in meeting these policy objectives are not at all clear. Moreover, the impacts of public investments in community capacities, private sector businesses, technical transfer activities, and public infrastructure need to be investigated more rigorously.

Current and anticipated studies:

- Life Cycle Assessment Model of the Use of Wildland Biomass from Forest Thinnings for Electrical Power Generation
- Institutional Barriers in the Utilization of Biomass from Forest Service Lands in California
- Western Utilization and Marketing Project: A Study of USFS Economic Action Program Utilization Grants and Contracts from 2001-2003
- Dry Forest Mechanized Fuels Treatments: A Demonstration Project and Biomass Utilization Opportunity Study
- Historical Uses of Biomass from US Forest Service Lands for Electrical Generation in California
- Costs and Revenues of Fuels Treatments in Regional Markets

Sub Problem 3: Adaptive Management and Community-Scale Collaborative Planning

The epicenter of public land and resources decision-making has shifted from inside the head of a line officer to the middle of a conference table. A broad range of public interest groups and individuals increasingly see their prerogative to participate in shaping the very questions and assumptions made in land management decisions. A growing body of research has focused on the community and social aspects of collaborative decision-making. However, a much smaller body of research exists on the political processes and power negotiation strategies inherent in all collaborative decision-making.

There are two key lineages of these processes that bear on USFS management and decision-making. First, is the oft-declared, but poorly delivered, commitment to Adaptive Management. The approach of this research program assumes that the difficulties in implementing Adaptive Management stem in large part from poorly negotiated power sharing agreements and loosely institutionalized process triggers in the system. The second key process is community-scale collaborative management. Success stories abound, but the perception of institutional failure appears to increase with time. Research is needed on the causes and predictors of successful collaborative adaptive management processes. Moreover, better planning and visualization tools are needed to help facilitate these key processes.

Current and anticipated studies:

- Adaptive Management Framework for the Lake Tahoe Basin's 2007 Regional Plan
- Institutional and Political Dimensions of Large Scale Adaptive Management Processes
- Spatial Analysis of Political and Planning Constraints on the Use of Biomass from Public Lands (resulting in the collaborative development of the "Universal Model Builder" software with University of California, Davis).

Anticipated Accomplishments and Benefits:

Specific research focus area would include:

- Landowners' and local officials' assumptions and expectations about forest health
- Drivers of private investment linked to public land and resource management activities
- Incentives and disincentives to participate in community-level collaborative planning and management
- Market barriers to new forest product development

The social and institutional side of resource management problems often is overwhelmed by the ecological uncertainty and the desire to address these prominent needs. We can actually more easily describe our scientific uncertainty around ecological issues than we can around social issues. Although we intuitively know problems exist, often we have difficulty specifically identifying problems dealing with stakeholder and public

participation within land management decision making. Furthermore, agency culture and long engrained habits cloud our recognition of barriers to more effective decision making and resource management.

Research within this problem area endeavors to bring more clarity and understanding to complex human issues and concerns, hopefully leading towards enabling institutional processes to "shed their skin" and evolve towards more effective approaches. In addition, the research results within this problem area will contribute to the more effective coupling of resource management activities with people and institutional management activities.

Future Direction in the Problem Area

There is a critical need to understand institutional and political processes in ways that help public agencies choose where to put their resources to their most effective use. Land management in the current socio-political climate is fraught with time consuming institutional processes (including administrative appeal provisions and legal challenges) and polarized political views. Significant levels of staff time and other resources are necessarily devoted to these activities; precious little is available for work that actually effects resource conservation and management. The controversial nature of issues and remedies results in satisfaction for virtually no one.

As increasing demand is put on public agencies to deliver more with less; managers need help understanding the institutional and political contexts and implications of their decisions. Research is needed to better and more objectively understand how these processes work and, in turn, do not work in land management and policy making. We already are unable to devote the level of effort we believe is needed to manage wildlands adequately, we need to learn to be more effective and efficient. A major step towards being able to do that is acknowledging the socio-economic and institutional barriers and opportunities that effect land management of wildlands.

Allocation of Scientist Resources Among Issue Areas

The research staff of this Research Unit is involved in multi-disciplinary work and thus allocation of resources strictly to one or another Issue Area is not expected. Most of the scientists in this unit cross over from one Issue Area to another, depending on their specific research project. Nevertheless the approximate or average annual allocation of Scientist Years, by Issue Area, is presented in the table below. This reflects current staff capabilities; additional expertise is envisioned to address the full array of task discussed above.

	Forest Function and Health	Conservation of Biological Diversity	Climate and Landscape Change	Water and Watershed Processes	Institutional and Policy Processes
Scientist Year	2.5	4.0	1.0	1.5	1.0
Costs Per Year	$500k	$800k	$350k	$350k	$200k

Approaches to Development of Applications, and Information Transfer:

Our scientists will endeavor to provide leadership and participation in regional, national, and international consortia dedicated to scientific research in the Sierra Nevada. Better knowledge about the nature and scope of the scientific issues in this region is expected to improve our understanding of ecological interactions within forest ecosystems, to provide high quality scientific information to manage resources (e.g., multiple forest values, water quality, and amenity resources), to help define ecologically and socially sustainable management practices, to establish scientifically defensible limits to management practices to ensure viability of species indigenous to the Sierra, and to anticipate changes in forest ecosystems. This knowledge will provide a scientific basis for understanding ecosystem composition, process, and function within this region and how this compares with similar and contrasting areas around the world. In conjunction with this basic scientific knowledge we will generate new information that will contribute to managing and sustaining forest resources now and in the future.

The emphasis of this Research Work Unit will be to address issues at multiple hierarchical levels of biological organization in the Sierra Nevada; the landscape and ecosystem, the community level, and the population level as well as multiple temporal scales. The nature of this work requires the full compliment of descriptive, retrospective, and experimental research. Fundamental knowledge as well as problems related to land management activities present the information needs that this unit will address directly and in collaboration with management units of the National Forest System. This Research Unit will work directly with the Region 5 Regional monitoring program for the Sierra Nevada Forest Plan Amendment to implement the elements of the program. Sampling designs for "status and change" monitoring requirements and hypothesis testing of key "cause and effect" questions will be a shared responsibility, with PSW scientists taking the lead in devising the sampling schemes and analyzing the results of the hypothesis testing work. PSW scientists will also take the lead in designing and executing the research needed to address the key information gaps identified in the Adaptive Management Strategy.

This research unit will also seek opportunities to collaborate with other scientific activities within the ecoregion and other ecologically similar regions. The details described below are intended to illustrate the nature of the issues within each of the four basic issue areas that this research unit would endeavor to address. This is intended to provide an idea of the research thrust of this unit but not to be limiting in the specific kinds of questions that would fall under the focus of this new research unit. Aspects of many of these questions are inter-related to questions within and among the four basic issues areas and ultimately we expect that the lines of research pursued will foster interdisciplinary approaches that include elements from a variety of questions listed below as well as other issues not mentioned here.

We plan to use these four areas of research emphasis as a means of organizing this unit into teams. Each of the four teams will include a number of principal investigators and associated staff. However, the integrated nature of this Unit and the work we do necessitates that each member of any given team work closely with other teams and in fact be associated with the work in other team areas.

An important focus of this unit will be the communication and integration of results for purposes of management application and scientific collaboration. The Sierra Nevada Research Center performs technology transfer and public outreach in several ways: development or evaluation of instruments and techniques, direct interaction with the public, resource managers, and written or otherwise published materials. Research may develop or evaluate certain instruments or techniques with regard to a specific Forest Service need. If the research is considered successful, then the implementation process would likely move to the National Forest System, a Technology Center, or other organization focused on the development and distribution of such technologies. Examples of this type of research include the evaluation of radar and laser altimetry to monitor forest structure in the Sierra Nevada, development and testing of satellite linked radio tracking transmitters, development of management strategies that improve the integration of resource concerns and fire management, and development of approaches to improve the quality and accuracy of vegetation information and projections of wildlife responses to vegetation change.

Organized field trips or workshops to disseminate research results and allow for interactive discussion with the public are important activities for a variety of the Center's projects including the following experiments: Kings River Sustainable Forest Ecosystem Project, the Blacks Mountain Interdisciplinary Ecological Research Project, the National Fire/Fire Surrogate study, and the Little Horse Peak project in the Goosenest Adaptive Management Area Project. In recent years field trips and workshops were held for congressional and forest user groups, the television and print media, foreign scientific delegations (including one from China), local historical societies, and a variety of groups from federal land management agencies. Members of the Center also participate in a variety of external workshops, field trips, and public and scientific meetings to share the knowledge they have acquired. The Center also provides technology transfer to promising students as well as teachers through venues including The California State University Fresno Research Methodology Program and the University of California Extension Forestry Institute for Teachers program; Center professionals also share their knowledge with students at educational institutions upon request. Publications transfer technology of the Center through outlets including scientific journals, proceedings and scientific reports published through the Pacific Southwest Research Station, books and book chapters, and various other publications.

We intend to accomplish Outreach through a variety of mechanisms:

- Publications. A variety of venues are anticipated including the highest quality scientific journals.

- Web site. We have built a web site for this unit that includes introductory information, summaries of research efforts, access to results of research, staff background and other relevant information. We intend to maximize use of web sites for updated communication.
- Fact sheets. We plan to develop one page "fact sheets" on each of our active projects as a concise means of informing interested parties on the essence of each of our active research projects. These are now available over the web and as hard copies.
- Periodic symposia/meetings. All scientists in this Center will participate in local, regional, national, and international meetings. We intend to organize meetings or workshops that focus on our research results by issue or geographic region. A first major effort is the Sierra Nevada Science Symposium, held October 7-10, 2002 at North Lake Tahoe, California (http://danr.ucop.edu/wrc/snssweb/snss.html)
- Coordination with Forest supervisors, their staffs, and other interested parties.

Environmental Analysis Considerations. Conducting and documenting environmental analysis of proposed research will be coordinated with National Forest System management and personnel. If an environmental assessment is needed, this Center will work with the appropriate National Forest and/or Ranger District to develop the proposed action. The National Forest System will perform the needed NEPA documentation and actions.

Identification of Cooperating Personnel and Facilities Available

The Sierra Nevada Research Center works closely with a number of other PSW research units. Given the multi-disciplinary nature of our Program Charter we will always seek collaborative research opportunities, particularly with PSW units which contain expertise not within our unit.

Examples of current research collaboration with other PSW units include:

- Disturbance Processes in California Conifer Types (Redding)
  - Effects of fire, insects, pathogens, and other disturbance factors on sustainability of forest ecosystems

- Atmospheric Deposition Impacts on Western Forest Ecosystems (Riverside)
  - Effects of air pollutants and climatically-driven changes on forested ecosystems to aid management to sustain and improve forest health

- Sustaining Wildlife Diversity in Dynamic Landscapes (Arcata)
  - How do we sustain wildlife diversity in dynamic landscapes subject to multiple resource demands?

We also take pride in our record of collaboration with other research institutions. Our entire staff of research scientists has engaged in numerous examples of collaborative

research with universities, other government scientists, and private sector scientists. Examples of current collaborative research activities include:

- Abundance, distribution, and population trends of oak woodland birds (California State University Fresno)
- Wildlife responses to the Blacks Mountain & Goosenest Ecological Experiments (Wildlife Conservation Society)
- Population Status and Habitat Use of Fishers (*Martes pennanti*) in the Kings River Administrative Study Area (UC Berkeley)
- High Mountain Lake Fish Stocking Studies (UC Santa Barbara)
- Response of subalpine conifers to 20th century climate variability in the Sierra Nevada and western Great Basin (Montana State University)
- Effects of Off-Highway Vehicles (OHV) on the composition and structure of vertebrate assemblages and their habitats (Humboldt State University)
- Teakettle Ecosystem Study: Fire and thinning effects on mixed conifer ecosystem structure and function (12 Institutions)
- Fire and fuels management, landscape dynamics, and fish and wildlife resources (PRBO Conservation Science, UC Davis, UC Berkeley)
- Potential applications of small modular biomass in rural community energy and economic development strategies (National Renewable Energy Lab)
- Forest Structure from Remotely Sensed Imagery (University of Maryland, University of Michigan)

The Sierra Nevada Research Center is necessarily spread out over a large geographic area with multiple facilities to serve our research mission. The San Joaquin Experimental Range is managed by the Sierra Nevada Research Center. In addition we have six experimental forests within the Sierra Nevada ecoregion and available for research activities. Currently we are active at the Teakettle Experimental Forest and the Blacks Mountain Experimental Forest although outstanding opportunities exist at the other four experimental forests. Our primary facilities include:

- Fresno Office (Forestry Sciences Laboratory) on California State University Fresno campus
- Davis Office (projected move onto UC Davis campus in Apr 2006)
- Albany Office (co-located with the Station Headquarters)
- San Joaquin Experimental Range in Madera County
- Teakettle Experimental Forest

- ☐ Blacks Mountain Experimental Forest
- ☐ Challenge Experimental Forest
- ☐ Onion Creek Experimental Forest
- ☐ Stanislaus-Tuolumne Experimental Forest
- ☐ Swain Mountain Experimental Forest
- ☐ Glen Meadow Work Center
- ☐ Dinkey Creek Work Center
- ☐ Plumas Work Center (in development)