U.S. Department of the Interior
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Western Ecological Research Center

Sierra Nevada Global Change Research Program

Sierra Nevada Forest Dynamics: Pattern, Pace, and Mechanisms of Change

Annual Report for Fiscal Year 2000

Compiled by

Nathan L. Stephenson and **Phillip J. van Mantgem**
U.S. Geological Survey, Western Ecological Research Center
Sequoia and Kings Canyon Field Station
47050 Generals Highway
Three Rivers, California 93271-9651

Principal Investigators
Lisa J. Graumlich
Jon E. Keeley
Nathan L. Stephenson
Thomas W. Swetnam
Dean L. Urban
Jan W. van Wagtendonk

Collaborators, Contributors, and Research Staff

R. Scott Anderson
Christopher H. Baisan
John J. Battles
Jonathan C. Beals-Nesmith
Andrew G. Bunn
Anthony C. Caprio
Mary E. Colberg
Mark M. Fain
Patrick N. Halpin
Malcolm K. Hughes
John King
Malia A. Laber
Sharie McKibben
Tana Meadows
Kurt M. Menning
Constance I. Millar
Carol Miller
Peggy E. Moore
Linda S. Mutch
Anne H. Pfaff
Kenneth B. Pierce
Veronica G. Pile
Linda I. Rivard
Phillip J. van Mantgem
Cynthia L. Withington

INTRODUCTION

The Sierra Nevada Global Change Research Program began in 1991 as a peer-reviewed, competitively-funded component of the National Park Service's (now USGS-BRD's) Global Change Research Program. While Sequoia, Kings Canyon, and Yosemite national parks form the core study areas of the program, the full study region encompasses adjacent public lands.

The goal of the Sierra Nevada Global Change Research Program is to understand and predict the effects of global changes on montane forests. By far the greatest limitation to understanding and predicting the effects of future global changes is the lack of a precise mechanistic understanding of how contemporary forest structure and function are controlled by the physical environment, disturbances, and biotic processes. Our research program therefore places landscape patterns within the context of the physical template (abiotic factors such as climate and soils), disturbances (such as fire), and biotic processes (demography, dispersal, growth, and competition). Our program focusses on developing a mechanistic understanding of this simple model as it applies to Sierra Nevada forests in particular, but also for the montane forests of western North America in general.

Our program consists of integrated studies organized around three themes: paleoecology, contemporary ecology, and modeling. The *paleoecological theme* takes advantage of the Sierra Nevada's rich endowment of tree-ring and palynological resources to develop an understanding of past climatic changes and the consequent responses of fire regimes and forests. The *contemporary ecology theme* takes advantage of the Sierra Nevada's substantive climatic gradients as "natural experiments," allowing us to evaluate climatic mechanisms controlling forest composition, structure, and dynamics. The *modeling theme* integrates findings from the paleoecological and contemporary studies, and is the indispensable vehicle for scaling up our mechanistic findings to regional landscapes, and predicting which parts of montane landscapes may be most sensitive to future environmental changes.

The Sierra Nevada Global Change Research Program currently focusses on addressing nine central sets of questions:

- What is the relative importance of topography and soil on site water balance in the Sierra Nevada, and how well does this compare with model predictions?
- What is the role and importance of reproduction in determining forest pattern and forest sensitivity to climatic change? By what mechanisms does climate control reproduction, and therefore forest sensitivity to climatic change?
- How do seed dispersal, seedling dynamics, and fine-scale variations in topography and soils interact with climatic change to affect forest sensitivity and change at local scales?
- How does climatic change affect the spatial extent, landscape pattern, and severity of fires?
- What are the relative importances of tree recruitment, death, and growth rates, and their interannual variabilities, in determining forest response to climatic variation in space and time?
- What portions of Sierra Nevada landscapes are most sensitive to climatic changes (temperature, precipitation, and seasonality), what are the implications of this for a greenhouse world, and what are the implications for land managers?
- Does climate synchronize fire regimes at subcontinental scales? If so, what large-scale climatic phenomena drive the synchrony?
- Can agents of pattern formation and mechanisms of forest change be generalized at subcontinental scales?

- How do the relative importances of agents of pattern formation vary among different climates? Is our understanding of mechanisms of forest change sufficient for a single model to explain forest dynamics at several different sites across the continent?

OVERVIEW OF PROGRESS AND RESULTS

In Fiscal Year 2000, good progress was made in addressing the nine central questions listed in the introduction. For example, we used data from our long-term forest plots to test some of the basic assumptions of models that predict forest responses to environmental change. We confirmed, for the first time in western coniferous forests, that there is the strong inverse relationship between tree growth rate and tree death rate, and we partitioned the relationship by causes of death. Mechanical causes of death may dominate what is considered "background" death that is independent of tree size and vigor, whereas biotic causes of death may be those most closely linked with growth rates. Additionally, we demonstrated that pre-fire growth rate is a significant determinant of post-fire tree survival, something that has not been considered in previous models of fire effects on trees. These and other data will help us modify and test our forest dynamics model.

Preliminary analysis of data from the newest component of our program, seedling dynamics, demonstrated that the relationship between seedling density and elevation closely follows a negative exponential function. These and other results are consistent with our earlier findings for saplings and mature trees, namely, that forest turnover is greatest in warm climates (low elevations), leading to population distributions skewed toward small and young trees. These findings have important implications for climatic effects on forest carbon cycling.

In 2000 we published, or had accepted for publication, 23 scientific manuscripts related to the Sierra Nevada Global Change Research Program. Some of these articles have received particular attention, such as Urban's article "Using model analysis to design monitoring programs for landscape management and impact assessment," published in *Ecological Applications*. Urban determined which portions of the southern Sierra Nevada landscape are potentially most sensitive to climatic change, and how this knowledge can be applied by managers to design monitoring programs. Feedback on this publication has been immediate, abundant, and enthusiastic.

We gave numerous talks and poster presentations at universities, professional meetings, and agency workshops. Perhaps most important and successful was our heavy involvement in a symposium entitled "Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences" at the annual meeting of the Ecological Society of America. This synthetic symposium was sponsored by the Western Mountain Initiative, which includes the Olympic, Glacier, Colorado Rockies, and Sierra Nevada global change programs. Topics addressed by members of the Sierra Nevada program included fire and climatic change, exotics and biodiversity, and past climatic changes and their effects on forests. The symposium generated substantial enthusiasm and both domestic and international queries for more information.

SPECIFIC ACCOMPLISHMENTS AND RESULTS

Our description of accomplishments and results for fiscal year 2000 are arranged according to the nine central questions that drive our program.

Question 1: *What is the relative importance of topography and soil on site water balance in the Sierra Nevada, and how well does this compare with model predictions?*

Ken Pierce (Urban's graduate student) continued to work with a network of about 24 HOBO temperature loggers, mostly in clusters of three to four loggers on contrasting slope facets at similar elevation. The goal is to use these data to develop regression-based methods of extrapolating temperature over complex terrain. Preliminary analyses of data from the summer of 1999 suggested that large-scale topographic features such as those governing cold air drainage may be more important that smaller-scale topographic features measured over 10's to 100's of meters.

In the summer of 2000 we augmented our sampling with 12 longer-lasting temperature loggers (HOBO Pro's, which will record data for 2 to 3 years). We developed a rotating-panel sampling design in which we install the long-term loggers at selected locations as benchmarks, then rotate cheaper HOBO Temp's, on a monthly schedule, at other topographic positions near the benchmarks. In this way, we can gather a denser spatial array of temperatures for use in our interpolation scheme.

In October of 2000 we re-deployed the CR10X dataloggers at low elevation (CCR-PIPO demography plot) and mid elevation (Log-SEGI demography plot) to record temperature and soil moisture over the winter. This ensures that we will be gathering these data in early spring, a crucial time relative to the dynamics of soil moisture. In previous years, we have missed these early-season measurements due to logistical difficulties in getting to the sites through the snow.

Question 2: *What is the role and importance of reproduction in determining forest pattern and forest sensitivity to climatic change? By what mechanisms does climate control reproduction, and therefore forest sensitivity to climatic change?*

This component of our program entered its second year. In each of 22 of our long-term forest dynamics plots (see Question 5, below), the 25×25 m seedling dynamics quadrats (two or more per plot) were revisited. All seedlings <1.37 m tall were again censused by size class, amounting to more than 31,000 seedlings which, over the coming years, will continue to be checked annually for growth and mortality. Additionally, all 415 seed traps (0.5×0.5 m) were revisited and had their contents removed, bagged, and stored for analysis during the winter.

Van Mantgem began preliminary analysis of the two years' worth of seedling data. Several patterns emerged immediately. The relationship between seedling density and elevation closely follows a negative exponential function. This finding holds true whether considering the density of all species, conifers only, pines only, or firs only (r^2 = 0.59, 0.58, 0.55, 0.56 respectively, $p < 0.001$ in each case). Across the elevational gradient, seedling populations are dominated by small seedlings (1 to 25 cm in height) relative to large seedlings (> 25 cm in height). These seedling findings are consistent with our earlier findings for saplings and mature trees, namely, that forest turnover is greatest in warm climates (low elevations), leading to population distributions skewed toward small and young trees.

Our two permanent plots that were prescribed burned had unusually high seedling densities. In the unburned plots, offspring-to-parent ratios (the total number of seedlings per parent tree) are significantly higher for conifers versus non-conifers (primarily oaks) and for firs versus pines. In the four plots where adult ponderosa pines were found, the offspring-to-parent ratios were significantly lower for ponderosa pine versus all other pines. These findings are consistent with the view that fire exclusion has favored fir reproduction at the expense of pine reproduction.

Question 3: *How do seed dispersal, seedling dynamics, and fine-scale variations in topography and soils interact with climatic change to affect forest sensitivity and change at local scales?*

The fullest expression of this effort must wait until we have several years of field data related to Questions 1 and 2, above. However, in the summer of 2000 we conducted a pilot study to prototype a new sampling design, called gradient focus plots, to elucidate the role of microenvironmental constraints (soil moisture, canopy closure) in governing seedling establishment, tree growth rates, and mortality. Urban's crew and USGS personnel surveyed a 40×140 m transect across a topographic saddle, thus spanning a topographic moisture gradient that ran from a xeric southwest-facing slope, over the saddle, and down a more mesic northeast-facing slope. Along this transect we surveyed each tree, sapling, and seedling to precise *x,y,z* coordinates using a laser surveying system and GPS. We also surveyed microtopography to create a high-resolution digital elevation model of the transect. We measured all trees, took short increment cores to determine growth rates, and harvested seedlings and saplings to age them. We also measured soil moisture (hand-held TDR), soil depth (tile probe), and canopy closure (spherical densiometer) at each seedling sampling point. While we are still processing these data, we have confirmed that the sampling design will provide the information we need to more fully understand the interplay between demography and microenvironment.

Graumlich's crew gathered data for modifying our forest stand simulation model to address ecotone dynamics. The crew established and surveyed three focus plots aimed at capturing demographic mechanisms and environmental constraints at fine spatial scales at the upper treeline ecotone. The focus of the sampling was to account for fine-scale variability in the physical environment as it affects seedling establishment and tree growth. The goal is to gather pilot data in the southern Sierra Nevada for foxtail and whitebark pine in hopes of capturing physical data that can be merged with life history traits.

Focus plots were established at three widely separated study sites at or near treeline along the Eastern crest of the southern Sierra Nevada. The general objective was to define sources of variability within a 20 m transect along the elevational gradient through:

- Sub-meter scale surveying to account for fine scale differences in topography,
- Measuring soil depth and moisture at many points within the transect,
- Measuring, locating, and determining growth rates of each tree from seedling through adult within the transect,
- Gathering soil samples and fine roots of destructively sampled seedlings to determine the existence and potential influence of mycorrhizae.

Data are being analyzed by Andrew Bunn, Ph.D. candidate at Montana State University, and results will be presented at the annual Landscape Ecology Symposium in Tempe, Arizona in April 2001.

Question 4: *How does climatic change affect the spatial extent, landscape pattern, and severity of fires?*

Analysis continued on existing fire scars within tree rings collected across four Sierra Nevada climatic (elevational) transects, and within the Giant Forest sequoia grove, the site of our intensive study of spatial patterns. Data were entered into the fire history database. Fire history transects in Yosemite and Sequoia-Kings Canyon were revisited, where 101 plots were sampled at twelve fire history sites to characterize understory and overstory vegetation and estimate pre-settlement forest type. This information will be used to tie pre-settlement forest type to fire-frequency estimates and gauge the direction and magnitude of post-settlement vegetation change. Additional fire history samples were also collected at the Biledo Meadow site outside of Yosemite National Park to aid in dating previously collected samples. A more complete understanding of the relationship between fire-frequency and forest type will underpin analysis of climate-fire relations and the effects of climatic change.

Considerable variability was noted within and between fire history sites in vegetation type and structure. This variation surely resulted in fine scale variability in fire patterns and may explain some of the "noise" in the relationships between fire frequency and elevation described in our previous work.

Question 5: *What are the relative importances of tree recruitment, death, and growth rates, and their interannual variabilities, in determining forest response to climatic variation in space and time?*

Our 23 long-term forest dynamics plots, established 1982 - 1994 and ranging in size from 0.9 to 2.5 ha, are arranged along a climatic (elevational) gradient from lower treeline (1500 m) to upper treeline (3100 m). All trees >1.4 m in height are tagged, mapped, and identified by species within each plot. In 2000, each of the more than 18,000 living trees within the plots received its annual mortality check. If a tree had died, probable causes of death were determined. All ingrowth (new trees reaching 1.4 m height) were mapped and tagged. Tree diameter remeasurements were completed in the plots that were due for their 5-yr remeasurements.

A basic assumption of most forest dynamics models is that a strong inverse relationship exists between tree growth rate and tree death rate. A few field studies have confirmed the assumption in the eastern United States, but none in western coniferous forests. Van Mantgem and Stephenson analyzed data from our five plots with the longest continuous records (17 to 18 years) to confirm the relationship in Sierra Nevada forests, then further broke down the analysis by causes of tree death: mechanical, biotic, or uncertain. Biotic and uncertain (the latter is probably mostly biotic) causes of death show a strong inverse correlation with tree growth rate. In sharp contrast, mechanical causes of death (such as breaking, falling, or crushing) show only a weak relation with growth rate. Thus, mechanical causes of death may dominate what is considered "background" death that is independent of tree size and vigor, whereas biotic causes of death may be those most closely linked with growth rates. Van Mantgem and Stephenson began a draft manuscript on these findings.

We have noted that current models of tree death following fire are inconsistent with models of tree death in the absence of fire (described above). Models of tree death following fire have focussed on extent of crown scorch, tree size, and other factors as predictors of mortality, but have consistently ignored tree growth rate as a predictor. Using data from our two long-term plots that were burned in 1990, we found that tree growth rate preceding a fire is a significant predictor of tree survival following the fire, at least for trees that have sustained <90% crown scorch. We are currently producing a manuscript on these findings.

Stephenson and others completed a manuscript on the importance of demography in determining forest carbon dynamics, which we submitted to *Science*. The manuscript made it to the review stage, but was then rejected. After some revision, we will re-submit the manuscript elsewhere.

Question 6: *What portions of Sierra Nevada landscapes are most sensitive to climatic changes (temperature, precipitation, and seasonality), what are the implications of this for a greenhouse world, and what are the implications for land managers?*

Urban's article on this topic, "Using model analysis to design monitoring programs for landscape management and impact assessment," was published in *Ecological Applications*. Urban used his Zelig model and its derivatives to determine which portions of the southern

Sierra Nevada landscape are most sensitive to climatic change, and how this knowledge can be applied by managers to design monitoring programs. Perhaps surprisingly, the areas occupied by high-elevation montane forest (red fir forest) may be the most sensitive to climatic changes, even though they are not considered water-limited. Feedback on this publication has been immediate, abundant, and enthusiastic.

Question 7: *Does climate synchronize fire regimes at subcontinental scales? If so, what large-scale climatic phenomena drive the synchrony?*

As described in our last annual report, fire-scar chronology networks have been compared among the west slope of the Sierra Nevada (45 sites), the Southwestern U.S. (63 sites), the east slope of the Cascades in Washington, and the Blue Mountains in Oregon (6 sites for Washington and Oregon combined). Each of these regional networks showed a tendency for high and low fire occurrence to be synchronized during certain years. Over the period 1700 to the present, high and low fire occurrence years were compared among the regions with an independent network of drought reconstructions from tree-rings, resulting in two primary observations: (1) During particular decades, high fire occurrence years in the Southwest correspond with low fire occurrence years in Washington and Oregon, and vice versa. During other decades there are no clear patterns of synchrony or asynchrony between the Southwest and Northwest. During some years the Sierra Nevada fire regime appears to be synchronized with the Southwest, and during other years it is synchronized with the Northwest. These patterns of decadal synchrony and asynchrony are evident during the two centuries analyzed with fire scars (i.e., 1700s and 1800s), as well as in time series of area burned derived from 20th century documentary records. (2) There are strong correlations between the spatial patterns of drought over the western United States and the patterns of synchrony and asynchrony of fire years in particular regions. Overall, we expect that these spatial-temporal patterns are important clues about the changing climatic controls over fire regimes at regional to continental scales, and probably reflect very broad-scale climatic patterns and their impacts, such as the El Nino-Southern Oscillation and the Pacific Decadal Oscillation.

Potential collaborations to further our work on this topic were discussed with Dr. Emily Heyerdahl (USDA Fire Lab, Missoula), Dr. Thomas Veblen (University of Colorado, Boulder), and Dr. Peter Brown (Rocky Mountain Tree-Ring Lab). Preliminary discussions have also been held with Dr. Alan Taylor (Penn State) regarding comparing our fire chronologies on the west slope of the Sierra Nevada with his chronologies from the eastern and northern Sierra Nevada. Improved regional and sub-regional fire-climate analyses will become possible with these comparisons of fire chronologies and climate reconstructions. Additionally, a proposal for a workshop in December 2001 on fire-climate studies in the western U.S. and western South America using paleoecological techniques is being prepared by Cathy Whitlock and Tom Swetnam for submission to the Earth System History program, National Science Foundation.

Question 8: *Can agents of pattern formation and mechanisms of forest change be generalized at subcontinental scales?*

Representatives of all of the Western Mountain Initiative (WMI) sites (Olympic, Glacier, Colorado Rockies, and Sierra Nevada) presented preliminary syntheses on several topics at a WMI-organized symposium ("Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences") at the annual meeting of the Ecological Society of America in Snowbird, Utah. The Sierra Nevada Global Change Research Program contributed heavily to three of the seven symposium talks: "1000 years of climate change and ecological response in western montane forests" (Graumlich); "Altered disturbance regimes: fire, fuels, and forest structure"

(Stephenson, Swetnam, and Veblen); "Exotic species and biodiversity in mountain forests" (Stohlgren, Keeley, and Graber). The four-hour symposium attracted hundreds of people, often at standing-room only densities. The symposium generated substantial enthusiasm and both domestic and international queries for more information. WMI members are considering producing a special series of papers based on the symposium.

Question 9: *How do the relative importances of agents of pattern formation vary among different climates? Is our understanding of mechanisms of forest change sufficient for a single model to explain forest dynamics at several different sites across the continent?*

This ambitious and seminal effort is the brainchild of Dr. Dean Urban (Duke University), and has been supported largely by his NSF Terrestrial Ecosystems [TECO] grant IBN #96-52656, with heavy local collaboration and integration with the Sierra Nevada Global Change Research Program. The TECO project is a model-based comparison of montane forest systems in the Oregon Cascades (H. J. Andrews Forest), the White Mountains of New Hampshire (Hubbard Brook Experimental Forest), and the southern Appalachians in western North Carolina (Coweeta Hydrologic Lab). As of this writing, Urban has reapplied to NSF/LTER for a continuation of funds in support of this cross-site comparison effort. Urban used summer 2000 to conduct a pilot study of two new sampling methods developed as part of this new proposal.

PROGRESS TOWARDS INTEGRATION WITH OTHER PROJECTS WITHIN RESEARCH THEME

The Western Mountain Initiative (Olympic, Glacier, Colorado Rockies, and Sierra Nevada) followed through on its August 1999 meeting in Spokane by presenting a symposium at the annual meeting of the Ecological Society of America in Snowbird, Utah. The symposium, "Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences," presented preliminary syntheses of results of studies on several stressors, including climatic change, altered fire regimes, non-native invasive species, air pollution, and land-use change. The symposium was quite well-attended (often standing-room only), and generated substantial audience enthusiasm.

Projects in the Western Mountain Initiative (WMI) are unified in seeking to understand and predict the effects of climatic change and other broad, systemic stressors on Western mountain ecosystems. The WMI sites differ from one another in the particular stressors and ecosystem components receiving greatest emphasis. Thus, much of WMI's project integration follows the model of the WMI symposium described earlier: different sites take the lead in integrating the results that are most closely aligned with their stressor(s) and ecosystem component(s) of emphasis. For example, in 2000 investigators from the Sierra Nevada supplied those in the Colorado Rockies with data on invasive species in the Sierra; the Colorado Rockies investigators are synthesizing the data.

Meeting the goal of understanding and predicting the effects of climatic change and other broad, systemic stressors on Western mountain ecosystems demands that integration involves not just investigators working at WMI sites, but also investigators working at a wide range of other Western mountain sites. In fiscal year 2000, for example, Swetnam of the Sierra Nevada program continued his collaboration with Tom Veblen of the Colorado Rockies program, aimed at determining whether climate synchronizes fire regimes at subcontinental scales, and if so, determining the large-scale climatic drivers of the synchrony. However, Swetnam additionally explored or formed collaborations with several other researchers not directly associated with

WMI sites, including Emily Heyerdahl (USDA Fire Lab, Missoula), Peter Brown (Rocky Mountain Tree-Ring Lab), and Alan Taylor (Penn State University).

Stephenson pursued the Sierra Nevada program's strength in climatic and fire effects on forest dynamics by continuing his collaboration with Jerry Franklin (University of Washington). Franklin oversees the only extensive network of long-term forest demography plots in western mountains. The collaboration included a manuscript submitted to *Science* (see "Question 5," above). Urban continued work on his model-based comparison of montane forest systems in the Sierra Nevada, the Oregon Cascades (H. J. Andrews Forest), the White Mountains of New Hampshire (Hubbard Brook Experimental Forest), and the southern Appalachians in western North Carolina (Coweeta Hydrologic Lab), seeking to determine the relative importances of agents of forest pattern formation among different mountain climates. Graumlich continued to expand her comparison of tree-ring records of climatic change from the Sierra to the northern Rockies and Pacific Northwest, and is independently seeking extra funding to compare treeline patterns in the Sierra Nevada and Glacier sites.

PLANS FOR COMING YEAR

Fiscal year 2001 will see a continuation of field work in all areas described in "Overview of Progress and Results." Stephenson, Keeley, and van Wagtendonk will oversee the major field efforts needed for re-censusing the more than 18,000 trees and 31,000 seedlings in our long-term demography plots, arrayed along a climatic (elevational) gradient. Swetnam will oversee sampling of fire scars at selected new fire history sites, aimed at filling holes in his data, and will oversee laboratory analysis and review of existing fire scar collections. Graumlich will establish additional treeline plots in support of Urban's modeling efforts, and Urban will continue field sampling in middle elevation forests.

On March 15-16, the principal investigators of the Sierra Nevada program (Stephenson, Keeley, van Wagtendonk, Urban, Swetnam, Graumlich, and Hughes) will meet in Tucson, Arizona, to compile draft chapters for a synthetic book on our results to date. The working outline for our book, including chapter authors, follows:

Sierra Nevada Forest Dynamics: Pattern, Pace, and Mechanisms of Change

1. Introduction: Overarching themes (Stephenson et al.)

THE PHYSICAL TEMPLATE

2. Contemporary climate and water balance (Stephenson)
3. Environmental correlates of contemporary forest distribution (Stephenson)
4. Scaling the physical template (Urban and Halpin)
5. Climatic variation in time: the late Holocene (Hughes and Graumlich)

DISTURBANCE

6. The role of fire in Sierra Nevada forests (van Wagtendonk and Caprio)
7. Scaling fire regimes in space (Chang, Miller, and Urban)
8. Temporal variation in fire regimes: the late Holocene (Swetnam, Baisan, and Caprio)

BIOTIC PROCESSES

9. Forest regeneration (Keeley)
10. Tree growth (Graumlich and Urban)
11. Tree death (van Mantgem and Stephenson)

INTEGRATION

12. Interactions, feedbacks, and couplings (Urban)
13. Scales of variability and the pattern, pace, and mechanisms of change
14. Synthesis and prospectus

Collaboration and integration with other WMI sites will continue as described under "Progress Towards Integration with Other Projects within Research Theme." Also, Swetnam will be working with Cathy Whitlock to secure funds for a workshop in December 2001, focussing on fire-climate studies in both the western U.S. and western South America. Additionally, WMI members are considering producing a special series of papers based on their well-received 2000 symposium, described earlier.

PRODUCTS

Reports, Abstracts, and Presentations

Graumlich, L. J. 2000. 1000 years of climate change and forest response in western mountains. Symposium Presentation, Ecological Society of America Annual Meeting, August 6, 2000, Snowbird Utah. (Abstract)

Graumlich, L. J. 2000. 1000 years of climate change and forest response in western mountains. Invited seminar, Department of Ecology, Evolution, and Behavior, University of Minnesota, November 15, 2000. (Presentation)

Keeley, J. E. 2000. Fire as a threat to biodiversity in California shrublands. USDA/USGS Planning for Biodiversity Conference, California State University, Pomona. June 2000. (Presentation)

Keeley, J. E. 2000. Determinants of plant species richness in Mediterranean-type shrublands. Symposium: Biodiversity in Mediterranean Ecosystems, MEDECOS VIII, Stellenbosch, South Africa. September 2000. (Abstract)

Keeley, J. E. 2000. Fire regimes changed by exotic plants. California Exotic Pest Plant Council Conference, Concord, California. October 2000. (Presentation)

Keeley, J. E. 2000. Fire and invasive in Mediterranean-climate ecosystems of North America. Fire Conference 2000: The First National Congress on Fire Ecology, Prevention, and Management. San Diego, California. November 2000. (Abstract)

Menning, K. M., J. J. Battles, T. L. Benning, and N. L. Stephenson. 2000. Forest litter densities under different canopy species in the mixed conifer forest of the southern Sierra Nevada: another factor affecting ground fire spread? *Abstracts*, Annual Meeting of the Ecological Society of America, p. 159. (Abstract)

Stephenson, N. L., T. W. Swetnam, and T. T. Veblen. 2000. Altered disturbance regimes: fire, fuels, and forest structure. *Abstracts*, Annual Meeting of the Ecological Society of America, p. 35. (Abstract)

Stohlgren, T. J., J. E. Keeley, and D. M. Graber. 2000. Exotic species and biodiversity in mountain forests. *Abstracts*, Annual Meeting of the Ecological Society of America, p. 35.

Swetnam, T. W. 2000. Spatial and temporal coherence of forest fire and drought patterns in western United States. International Conference on Dendrochronology for the Third Millennium, Mendoza, Argentina. 2-7 April, 2000.

Swetnam, T. W. 2000. Disentangling the effects of climate and people on pre-20th century fire regimes. American Geophysical Union, Fall 2000 Meeting, Special Session, B14 - Land Use Change, I, A Paleoenvironmental Perspective on Ecosystem Sustainability. December 19, 2000.

van Mantgem, P. and M. W. Schwartz. 2000. Cambial heat resistance in understory in Californian mixed conifer forests. Ecological Society of America 85th annual meeting. August 6 - 10, 2000 Snowbird, Utah. (Abstract)

van Wagtendonk, J. W. 2000. Fire use management: new policies, new philosophies? Advanced Fire Use Applications course, National Advanced Resource Technology Center, Marana, Arizona, February 13, 2000; and Boise, Idaho, March 26, 2000. (Presentation)

van Wagtendonk, J. W. 2000. A quarter century of burning in the Illilouette Creek watershed. Fire Conference 2000: The First National Congress on Fire Ecology, Prevention, and Management. San Diego, California, November 27, 2000. (Abstract)

Publications

Agee, J. K., B. Bahro, M. A. Finney, P. N. Omi, D. B. Sapsis, C. N. Skinner, J. W. van Wagtendonk, and C. P. Weatherspoon. 2000. The use of shaded fuel breaks in landscape fire management. *Forest Ecology and Management* 127:55-66.

Arbaugh, M. J., S. Schilling, J. Merzenich, and J. W. van Wagtendonk. 2000. A test of the strategic fuels management model VDDT using historical data from Yosemite National Park. Pages 85-89 *in* L. F. Neuenschwander and K. C. Ryan (tech. eds.), *Proceedings of the Joint Fire Sciences Conference and Workshop*, Vol. II. University of Idaho and International Association of Wildland Fire. 312 p.

Bunn, A. G., D. L. Urban, and T. H. Keitt. 2000. Landscape connectivity: a conservation application of graph theory. *Journal of Environmental Management* 59:265-278.

Graumlich, L. J., and M. Ingram. 2000. Drought in the context of the last 1000+ years: some surprising implications. Pages 234-242 *in* D. Wilhite (ed.), *Drought: A Global Assessment.* Routledge Press, New York.

Graumlich, L. J. 2000. Global change and wilderness areas: disentangling natural and anthropogenic changes. Pages 27-32 *in* S. F. McCool, D. N. Cole, W. T. Borrie, and J. O'Loughlin, compilers. *Wilderness Science in a Time of Change Conference -- Volume 3: Wilderness as a Place for Scientific Inquiry.* Proceedings RMRS-P-15-VOL-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Keane, R. E., R. Burgan, and J. W. van Wagtendonk. *In Press*. Mapping of fuels for fire management across multiple scales: integrating remote sensing, GIS, and biophysical modeling. *International Journal of Wildland Fire*.

Keeley, J. E. and M. Baer-Keeley. *In press*. Restoration with smoke-dependent species. *Ecological Restoration*.

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Other Products (Advice and Assistance)

-- Federal task force for creation of the new Giant Sequoia National Monument (Stephenson)

-- Provided information for NPS Director Stanton's testimony to Congress on the Los Alamos fire (Stephenson)

-- Frequent advisor to USDA Forest Service on ecology and management of giant sequoia groves (Stephenson)

- -- Advice and assistance to U.C. Merced, Yosemite, and Sequoia and Kings Canyon national parks on research goals in the Sierra Nevada, and planning for cooperative research (van Wagtendonk, Stephenson, and Keeley)
- -- Advice on establishing fire management objectives for Redwood National Park and the southern California parks and monuments (Keeley)
- -- Advice on planning Sequoia - Kings Canyon National Parks monitoring program (Stephenson, van Wagtendonk, Keeley)
- -- Advice on planning Sequoia - Kings Canyon National Parks' vegetation mapping effort (Stephenson, Keeley)
- -- Advice and assistance to Sequoia - Kings Canyon National Parks in updating their Resources Management Plan (Stephenson, Keeley)
- -- Advice to Sequoia - Kings Canyon National Parks on goals for fire management (Stephenson, van Wagtendonk, Keeley)
- -- Many other similar activities.

WEB PAGE REVIEW

UPDATED SIS DESCRIPTION